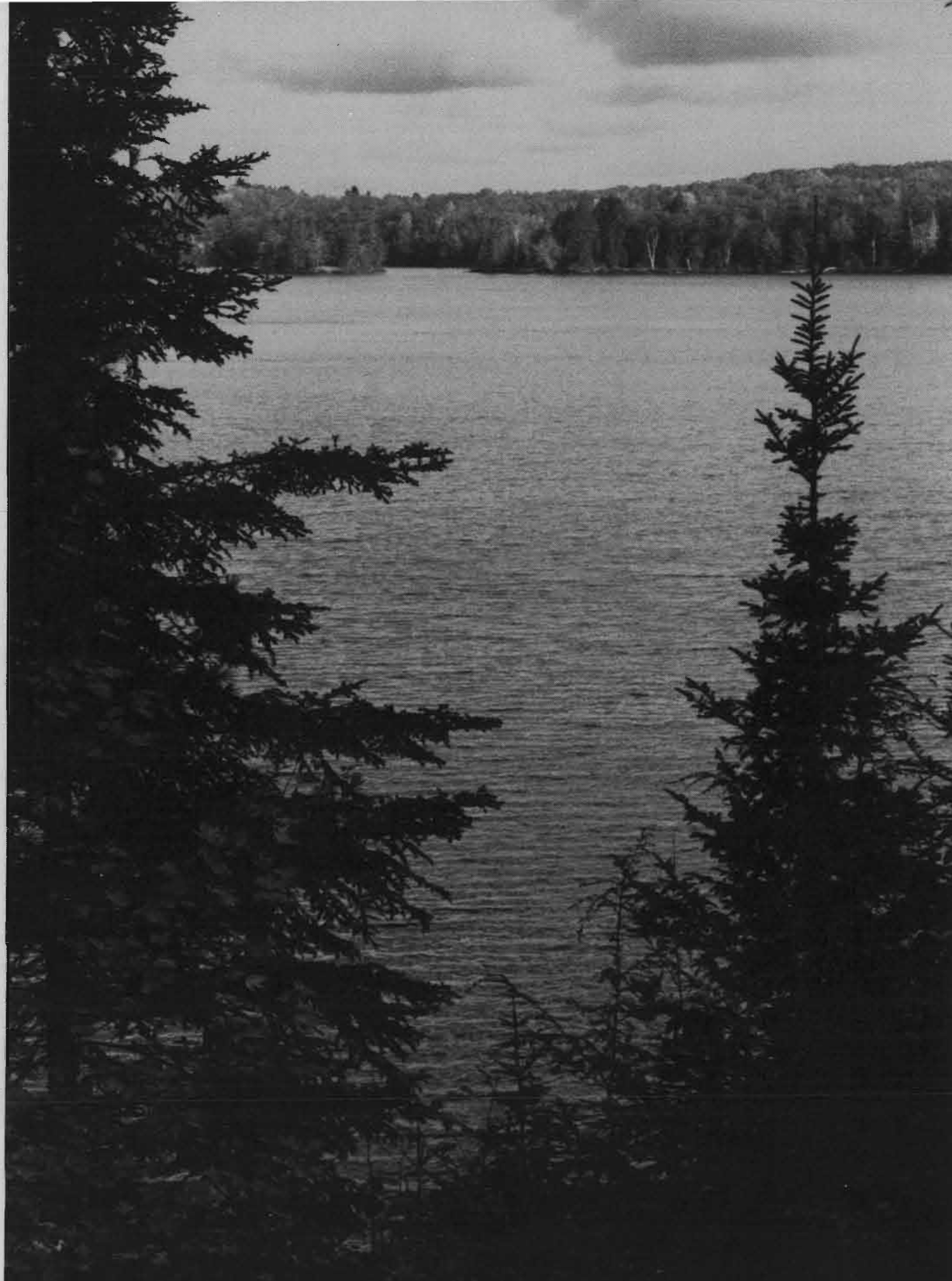

Mercury Levels in Walleyes from Wisconsin Lakes of Different Water and Sediment Chemistry Characteristics

Technical Bulletin No. 163
Department of Natural Resources
Madison, WI 53707

1989

COVER: Photo of White Birch Lake by R. Lathrop

ABSTRACT

Forty-three lakes throughout Wisconsin were sampled in 1985-86 to determine the water and sediment chemistry characteristics that were associated with elevated concentrations of mercury in walleyes *(Stizostedion vitreum vitreum* (Mitchill)). Mean mercury concentrations for each of three different length classes of walleyes increased as the parameters lake pH, alkalinity, calcium, conductivity, or chlorophyll-*a* decreased. Low values for these parameters characterized most lakes in northern Wisconsin. Mean mercury concentrations exceeded the Wisconsin health standard of 0.5 μg Hg/g wet weight of fish for all walleye length classes in lakes with pH values <6.0, for walleyes ≥15.0 inches in lakes with pH 6.0-6.9, and for walleyes ≥20.0 inches in all lake pH categories. Apparently the older, larger walleyes in hard-water as well as soft-water lakes can accumulate enough mercury to warrant concern. Sediment mercury concentrations were generally ≤0.2 μg/g dry weight for all study lakes, but sediment mercury and organic matter were higher in lakes with pH values <7.0 than in lakes with pH ≥7.0. Models were developed and tested to predict mercury concentrations in a 17-inch walleye for each lake. The best model derived from our study and tested on an independent dataset used alkalinity and calcium as independent variables. Clearly, walleyes from soft-water, poorly buffered, low pH lakes have the highest concentrations of mercury, but the reasons for these higher concentrations require further study.

KEY WORDS: Walleye *(Stizostedion vitreum vitreum)*, walleye mercury concentrations, water chemistry analyses, sediment chemistry analyses, sediment mercury concentrations, sediment organic content, Statistical Analysis System, Hakanson model, three-variable model, two-variable model, walleye length class.

MERCURY LEVELS IN WALLEYES FROM WISCONSIN LAKES OF DIFFERENT WATER AND SEDIMENT CHEMISTRY CHARACTERISTICS

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Technical Bulletin No. 163
Department of Natural Resources
P. O. Box 7921, Madison, Wisconsin 53707

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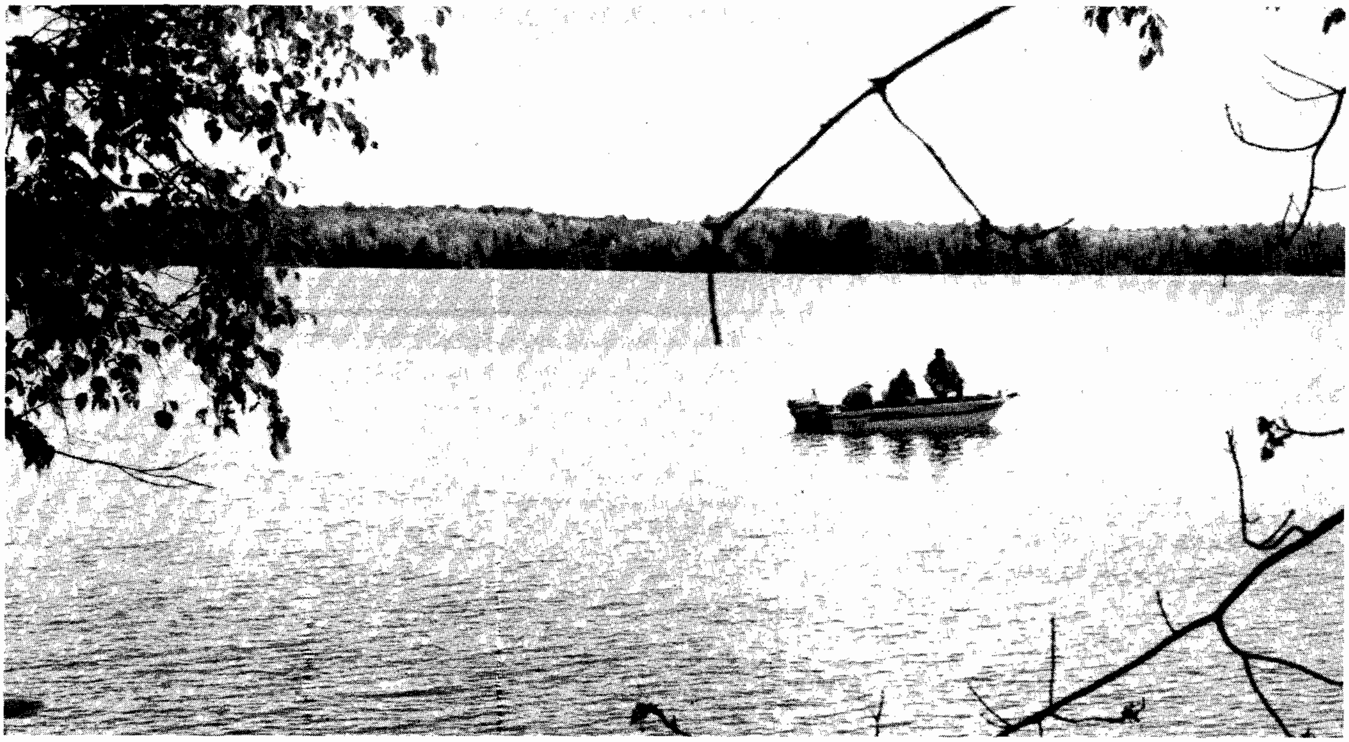


INTRODUCTION

Mercury contamination of the aquatic environment became well known as a serious problem after the tragedy of Minamata, Japan, in the 1950s. A rash of deaths, neurological disorders, and birth defects were traced to a diet of fish and shellfish contaminated with mercury from industrial wastes (U.S. Dep. Health, Educ., and Welfare 1970). Numerous other cases of mercury poisoning of humans and piscivorous wildlife were reported throughout the world in the 1960s (Sheffy 1987). This new awareness resulted in the U.S. Food and Drug Administration (FDA) establishing a limit of 0.5 µg Hg/g wet weight in fish marketed for human consumption.* In the late 1970s the FDA limit was increased to 1.0 µg/g. In 1986 Wisconsin lowered its standard to the current 0.5 µg/g.

Simultaneously, studies in Scandinavia and Canada showed that many lakes that had not received industrial discharges contained fish with high concentrations of mercury (Johnels et al. 1967, Wobeser 1970). These lakes were poorly buffered and were being acidified by precipitation.

In Wisconsin, testing for mercury in fish began in the early 1970s, after the Wisconsin Department of Natural Resources (DNR) and other environmental groups became aware of the seriousness of mercury contamination in the environment. High mercury concentrations in fish and sediments were discovered in waters that had received industrial discharges containing mercury wastes (Kleinert and Degurse 1971, Konrad 1971). As the association between high fish mercury concentrations and remote, soft-water lakes was further documented in the 1970s, the DNR's fish-testing program shifted its focus to soft-water lakes in northern Wisconsin. After a study by Wiener (1983) found elevated mercury concentrations in fish from several Wisconsin lakes with low pH, the DNR began to monitor the region's lakes with both the lowest pH and abundant predator fish populations (Lee Liebenstein, Wis. Dep. Nat. Resour., pers. comm. 1987).

As a result of this testing, 14 lakes were placed on an official health advisory released by the DNR and the Wisconsin Division of Health in April 1985. The advisory used the Wisconsin standard of 0.5 µg/g and the fact that the half-life of mercury in humans is 70-80 days (Miettinen et al. 1971). The advisory sought to limit mercury consumption so that no more than 1.5 µg would accumulate in tissue. Children and pregnant and nursing women were identified as being at particular risk from mercury contamination. As more lakes were tested, further health advisories were issued in July 1986 and April 1987, when 52 and 90 lakes, respectively, were identified as having elevated mercury concentrations in predator fish, including walleye (*Stizostedion vitreum vitreum* (Mitchill)).

From the 1985 fish advisory, particular concern arose about the extent of mercury contamination of walleye in Wisconsin's soft-water lakes, most of which are located in northern Wisconsin's tourism region. Because the walleye has traditionally been one of Wisconsin's most prized game species for sport fishing as well as eating, the potential impact to the people of northern Wisconsin was serious. This region has also received considerable attention about the effects of acid deposition on its poorly buffered lakes.

The objectives of our study, which began in late spring of 1985, were to provide information about the mercury contamination of walleyes in lakes throughout the state and to document the water and sediment chemistry characteristics associated with high concentrations of mercury in fish. Additional objectives were to test a Swedish model (Hakanson 1980) that predicted fish mercury concentrations from lake data and to evaluate or develop a predictive model that could help identify other Wisconsin lakes with contaminated fish. To provide background material, we also reviewed the scientific literature concerning the cycling of mercury in lakes and the uptake of mercury by fish.

* The unit of µg Hg/g wet weight is also referred to as ppm (parts per million).

BACKGROUND

Mercury Cycle

Mercury exists in many forms in the atmosphere, water, soil, and sediments. Some important inorganic forms are elemental mercury (Hg^0), divalent mercury (Hg^{+2}), and mercuric sulfide or cinnabar (HgS). Elemental and divalent mercury are the predominant forms in the atmosphere and water (Kudo et al. 1982), while cinnabar is commonly found in mineralized soils and sediments. Of the organic forms, methylmercury (CH_3Hg^+) is of particular significance. Although present in small amounts (Kudo et al. 1982), methylmercury is important in aquatic systems because it can accumulate in organisms (Westoo 1973) and cause severe health problems in humans.

Atmospheric mercury originates from both natural and anthropogenic sources. Natural processes such as volatilization from soil and rocks, volcanic activity, vaporization from aquatic systems, and biological activity account for most of the naturally released mercury in the atmosphere (Natl. Acad. Sci. 1978). Anthropogenic sources of mercury in the atmosphere include power plant emissions, cinnabar mining operations, and other manufacturing and industrial processes (Quinn 1985). The global atmospheric mercury burden has increased in the past century with anthropogenic sources now accounting for 25-30% of the total (Andren and Nriagu 1979). Mercury cycles continuously through the environment, returning to the earth primarily in rain and snow and through gas exchange with aquatic surfaces (Natl. Acad. Sci. 1978).

The mercury cycle in lakes includes sediments, water, and biota. Besides the naturally existing mercury in sediments and water, mercury may come from anthropogenic sources. Sources of this mercury may be sewage or industrial effluents (Syers et al. 1973) or industrial emissions entering lakes in precipitation. Because atmospheric mercury remains in the air for up to 11 days (Natl. Acad. Sci. 1978), it can be transported over long distances, entering a watershed far from the point of emission. Consequently, even lakes in remote areas could receive significant amounts of mercury.

The low solubility of elemental mercury in water and the tendency for divalent mercury to complex with dissolved and particulate matter result in rapid deposition of mercury into the sediments of aquatic systems (Kudo et al. 1982). Over 90% of the mercury in lake systems is in sediments (Faust and Aly 1981), though only a small amount is available to biota (Jernelov 1972). Divalent mercury forms largely insoluble complexes with minerals in sediments, and only certain aerobic bacteria that cannot live in the deeper anoxic sediments can release the mercury for other uses.

The mercury in surficial sediment layers is used by microorganisms to transform inorganic mercury into methylmercury. These sediment microbes are the primary source of methylmercury, though some biological methylation also occurs in the water column (Furutani and Rudd 1980, Xun et al. 1987) and in the mucus of the bodies and intestinal tracts of fish (Rudd et al. 1980). In addition to biological methylation, some chemical methylation of inorganic mercury may take place by the action of ultraviolet light in the surface waters (Summers and Silver 1978).

Microorganisms produce two forms of methylmercury, monomethyl- and dimethyl-mercury. Dimethylmercury is produced in small amounts and is volatile, escaping easily from the water column (Wood 1974). Dimethylmercury is not taken up readily by fish. Conversely, monomethylmercury is less volatile and diffuses rapidly across cell membranes to bind with sulfydryl groups in proteins. This binding maintains a concentration gradient favorable for continual diffusion into fish.

Methylmercury is released into the water column by microbes and taken up by fish and other organisms. Fish accumulate methylmercury primarily by eating contaminated food and by extracting mercury from water passing across their gill membranes during respiration (Phillips et al. 1980, Rodgers and Beamish 1983). Accumulation is rapid due to the sulfydryl-group affinity of methylmercury; depuration, or release, is slow because of its high lipid solubility (Jernelov et al. 1975). The half-life, or time required to remove 50% of the mercury from the body, is 700 days for northern pike (Phillips and Buhler 1978), compared to 70-80 days for humans. Thus, continual uptake and slow depuration may explain why older, larger fish tend to be more contaminated than smaller fish of the same species in similar lake conditions (Kleinert and Degurse 1971, Phillips et al. 1980). Also, piscivorous species, such as walleye and northern pike, tend to contain more mercury than planktivorous species (Scott 1974, Glazer and Bohlander 1978, Bloomfield et al. 1980, Phillips et al. 1980), in part because of the position that piscivorous species occupy in the food chain (Jernelov 1972).

Many microorganisms also demethylate mercury (Spangler et al. 1973), and the balance between methylation and demethylation may be an important determinant of the amount of methylmercury available to fish and other organisms. This balance may be affected by changes in the mercury input to the system and changes in the mobilization and cycling of the existing mercury as water conditions such as lake acidification vary.

Lake Factors Affecting Mercury Uptake Rate by Fish

Studies have shown negative correlations between pH and mercury concentrations in fish. Wiener (1983) found that older walleyes from naturally acidic lakes in northern Wisconsin contained significantly more mercury than similarly aged fish from circumneutral lakes in the same area. One year after a lake in northern Wisconsin was artificially acidified from a pH of 6.0 to 5.5, yellow perch contained significantly more mercury than before the acidification (Wiener 1986). Studies on northern pike (Hakanson 1980, Verta et al. 1986) and sunfishes (Wren and McCrimmon 1983) showed a similar negative relationship between lake pH and fish mercury concentrations.

Researchers have investigated the mechanisms influencing methylation rate. Decreasing the pH in anoxic sediments below the surface layers decreased the methylation rate (Ramlal et al. 1985), while in aerobic surficial sediments the methylation rate increased with decreasing pH (Xun et al. 1987). Verta et al. (1986) suggested that decreased pH may reduce the adsorption of mercury to particulate matter, making it more available for methylation or uptake. Low pH conditions were found to increase mucus production in fish, which could result in additional mercury methylation (Varanasi et al. 1975).

Scheider et al. (1979) reported that lakes with alkalinities <300 µeq/L contained walleyes with higher mercury concentrations than walleyes of similar lengths from lakes with higher alkalinities. Akielaszek and Haines (1981) suggested that low alkalinity waters have less particulate matter with which mercury can complex, resulting in more unbound mercury available to fish and microorganisms. Low calcium (Ca^{+2}) waters also contained fish with high mercury concentrations. Researchers thought the uptake of mercury by fish in these waters was affected by calcium-mediated changes in gill permeability (Rodgers and Beamish 1983). At pH values >6.0 the effect of pH was minimal, though calcium effects were still important (McWilliams and Potts 1978). Overall, evaluating the effects of pH on methylation rate is difficult because of the confounding effects of low calcium concentrations and low alkalinities in low pH waters.

Organic content of a lake may affect mercury availability. Inorganic and organic mercury easily adsorb to and form complexes with dissolved and particulate organic matter (Faust and Aly 1981, Rudd et al. 1983). How this relationship affects fish mercury concentrations is unclear because of other important factors, such as lake productivity and lake ionic content. Productive lakes have high organic content from internal primary production. D'Itri et al. (1971) found that fish in more productive lakes contained the smallest amount of mercury. Along with Jernelov (1972), D'Itri et al. suggested that the anoxic conditions of eutrophic lakes facilitated the formation of mercuric sulfide. This mercury cannot be released except by microbes in aerobic conditions. Because of the high organic content of productive lakes, some of the mercury that has complexed with particulate matter will settle into the sediments where mercuric sulfide can form (Hakanson 1980).

Other lakes may be highly organic yet unproductive. Some reservoirs in Finland (Verta et al. 1986) and lakes in northern Minnesota and northern Wisconsin are highly organic because of humic input from surrounding bog areas (Lillie and Mason 1983, Helwig and Heiskary 1985). These organic, unproductive water bodies contain fish with high concentrations of mercury (Helwig and Heiskary 1985, Verta et al. 1986).

Again, pH is a confounding factor in these studies that prevents a clear understanding of the details of the relationship of organic matter, lake productivity, and fish mercury concentrations. The unproductive waters tended to have low ionic content and high fish mercury concentrations, while the productive waters tended to have high ionic content and low fish mercury concentrations. Lake pH may affect the associations of mercury with particulate and dissolved organic matter, making mercury more or less available to fish and microorganisms. Therefore the relationship among lake pH, organic content, the amount of mercury in the system, and the relative amounts of dissolved and particulate organic content may be an important determinant of how much mercury ultimately will accumulate in fish.

Other lake chemistry characteristics may influence the mercury concentrations in fish. Higher temperatures increase metabolic rate and mercury uptake (MacLeod and Pessah 1973, Rodgers and Beamish 1981). These results suggest that seasonal and geographic temperature variability will affect mercury uptake. The species mix of microbes (Natl. Acad. Sci. 1978) and the availability of sulfur and iron, which complex with mercury and each other, can also affect the availability of mercury for methylation and uptake (Rudd et al. 1983).

These studies show clearly that water bodies containing fish with high concentrations of mercury share five characteristics: (1) low pH (Jernelov et al. 1975; Hakanson 1980; Stokes et al. 1983; Wiener 1983, 1986; Wren and MacCrimmon 1983; Helwig and Heiskary 1985); (2) low alkalinity (Scheider et al. 1979, Akielaszek and Haines 1983, Helwig and Heiskary 1985); (3) low calcium (Helwig and Heiskary 1985); (4) low productivity (D'Itri et al. 1971); and (5) high dissolved organic content (Helwig and Heiskary 1985, Verta et al. 1986).

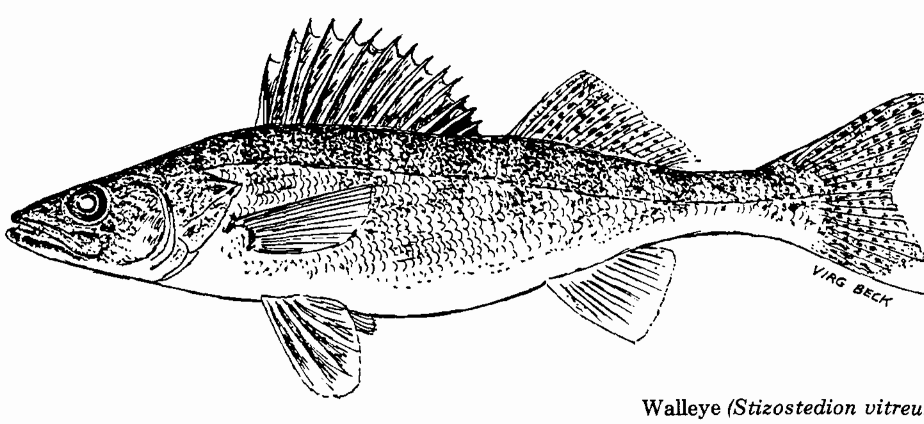
Northern Wisconsin contains many lakes with these limnological characteristics (Lillie and Mason 1983). By April 1986, 90 lakes mostly in this region had been identified as containing contaminated fish. Part of the mercury may come from natural sources because few Wisconsin lakes suffer from point source mercury contamination. Increases in atmospherically borne mercury, however, may have increased the mercury levels in lakes in the past century. In those lakes with low buffering capacity, acid deposition could increase the availability of mercury to fish by lowering the lake pH and reducing the alkalinity.

STUDY AREA

Forty-three lakes throughout Wisconsin were sampled for this study. The lakes were selected to represent a broad range of pH and alkalinity. Included were both the acid-sensitive, low alkalinity lakes of northern Wisconsin and the hard-water lakes of southern Wisconsin. Although there are many more soft-water than hard-water lakes in Wisconsin (Lillie and Mason 1983), our initial study was designed to sample 10 lakes in each of four pH ranges: <6.0, 6.0-6.9, 7.0-7.9, and $\geqslant 8.0$. The Surface Water Inventory (SWI) of Wisconsin's lakes was used in the selection process (Wis. Dep. Nat. Resour. n.d.).

The most important criterion for lakes selected in each pH category was the presence of walleye, which was determined from an SWI list of fish species. We also used other important criteria: lake area >20 ha, lake depth >3 m, public access, and location proportional to the distribution of natural lakes in Wisconsin. Impoundments and flowages were not selected because the deposition of sediments is increased by large river inflows. Flowages and interconnected lakes were also avoided to ensure that each fish collected would have spent most of its life in the same lake. Lakes with simple basin morphometry were preferred to those with more complex morphometry.

While the above criteria were used in the selection process, some trade-offs had to be made. Our study depended on the DNR Bureaus of Fisheries Management and Water Resources Management for the collection and processing of fish for mercury analyses. The schedule for fish collections had previously been decided by the bureaus for most of our study lakes. We tried to be objective in selecting lakes from the bureau lists. To have enough lakes in each of the four pH ranges, we requested that additional lakes be added to the list. Fish sampling from 10 of the 43 lakes was conducted by personnel from the DNR Bureau of Research.



Walleye *(Stizostedion vitreum vitreum* (Mitchill))

METHODS

SAMPLE COLLECTION AND ANALYSIS

Water

Water parameters and constituents tested were Secchi depth, water temperature, dissolved oxygen, pH, total alkalinity, calcium, total phosphorus, chlorophyll-*a*, conductivity, and color. Each study lake was sampled twice during the summer of 1985 (late June to August) and once each during the following fall and winter. Chlorophyll-*a* was omitted from the winter sampling, and color and conductivity were omitted from one summer sampling date.

Lakes were sampled at the location of their deep holes. Secchi disc readings were measured with a 20-cm diameter black and white disc. Water samples were collected with a 2.2-liter Plexiglas Kemmerer sampler. To determine thermal stratification, vertical profiles of water temperature and dissolved oxygen were taken using a resistance thermometer and the modified Winkler method (Am. Public Health Assoc. 1976), respectively. In addition, pH samples were collected at water depths to characterize the trophogenic and tropholytic zones; the deepest sample was taken 1 m above the lake sediments to represent the pH at the sediment-water interface. Water samples for the other constituents were collected just below the lake surface, except for the chlorophyll-*a* sample, which was a 0-2 m composite.

Alkalinity, pH, and dissolved oxygen samples were analyzed immediately upon return to shore. After initial calibration of the pH meter to buffers of pH 7.0 and 4.0, all pH measurements for the sample depths were determined. Part of the surface sample was titrated with 0.02 N H_2SO_4 to a fixed pH end point of 4.5. If the alkalinity was <500 µeq/L, the remaining sample was chilled, and a Gran titration was run later at our field station laboratory. Color was measured with the Helliage Aqua Tester (#611A) upon return to the field station. Conductivity and chlorophyll-*a* analyses (Kopp and McKee 1979) also were run at this time. The lake water for chlorophyll-*a* analysis was filtered in the field through Gelman A/E glass fiber filters. The filters were placed in tubes containing 5 ml of 90% acetone, stored on ice, and later transferred to a lab freezer. The filters were then ground, and the extract was centrifuged before analysis using the Trichromatic technique (Kopp and McKee 1979). Water samples for total phosphorus and calcium analyses were preserved with sulfuric acid and nitric acid, respectively, and chilled until analyzed by the State Laboratory of Hygiene (SLOH) in Madison later in the week (Kopp and McKee 1979).

Field testing for pH, alkalinity, and dissolved oxygen.

Because of the wide geographic distribution of the 43 study lakes and the extensive effort required to obtain the sediment samples, two field crews conducted the two summer lake water samplings. All field and laboratory analysis techniques and instruments were the same, except for the use of two different battery-operated pH meters (Sargent Welch model PBL and Beckman model 21) and two electrodes of the same model (Beckman Futura II Star combination electrode). The pH readings were compared extensively in the lab during the summer and in the field during the fall by using different electrodes with the same meter and different meters with the same electrode. The results consistently varied by less than 0.2 pH units over all pH ranges sampled; the variation contributed by the different electrodes and different meters was similar.

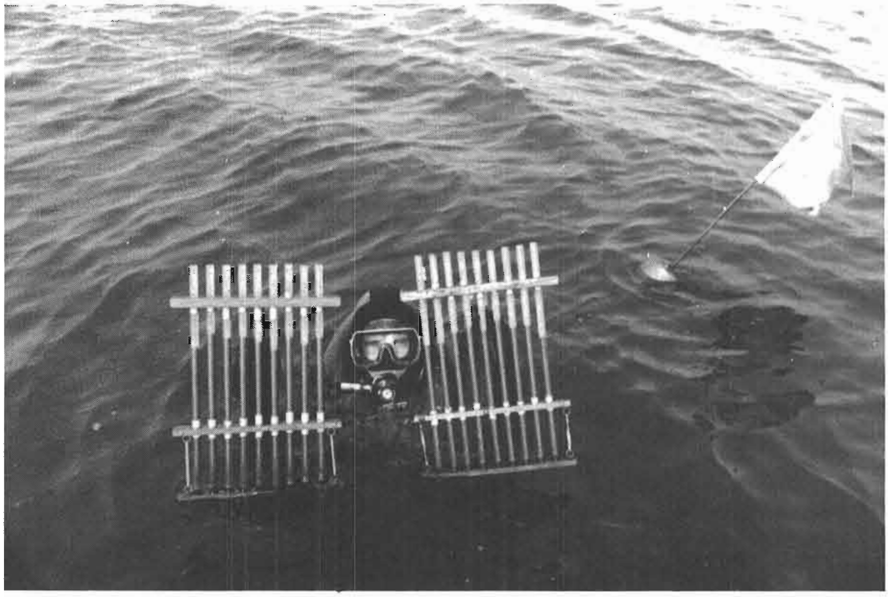
Sediment

The bottom sediments of each lake were sampled during one of the summer water chemistry sampling periods. Sediment samples were collected by a scuba diver using samplers designed for this project. Each sampler consisted of a series of nine Plexiglas ½-inch diameter tubes, which were aligned in a wooden rack with a handle. The diver swam along the lake bottom with the sampler tubes held just under the undisturbed sediment-water interface. This method allowed for large quantities of the most recently deposited sediments to be collected. The sediment depth sampled was <2 cm, with most of the material entering the tubes from depths <1 cm. After the tubes were filled, one end was capped with a rack of rubber stoppers; then a second set of tubes was filled and capped before the diver ascended to the lake surface. In the boat, each rack of tubes was held vertically, allowing sediments to settle to the bottom. The excess water in the tubes was then removed with a pipette before the sediments were composited and transferred to plastic sample bottles. This technique was particularly effective in collecting large amounts of flocculent sediments.

The deeper lakes, which contained a distinct thermocline and hypolimnion, were sampled at three water depths. Sediment samples were taken near the deepest location, in a mid-depth location subtended by the thermocline, and in a shallower area >3 m in depth. Only two samples were collected in moderately deep lakes having no distinct hypolimnion. In the shallow, nonstratified lakes, only one sediment sample was taken. In a few of the deeper lakes, dense macrophyte beds in the shallow zone prevented sediment samples from being taken.

After collection, the sediment samples were stored immediately on ice in the field and transferred to freezers at DNR or University of Wisconsin field stations as soon as possible, in order to minimize volatilization of mercury. Most of the samples were frozen within 36 hours, depending on the length of the field trip.

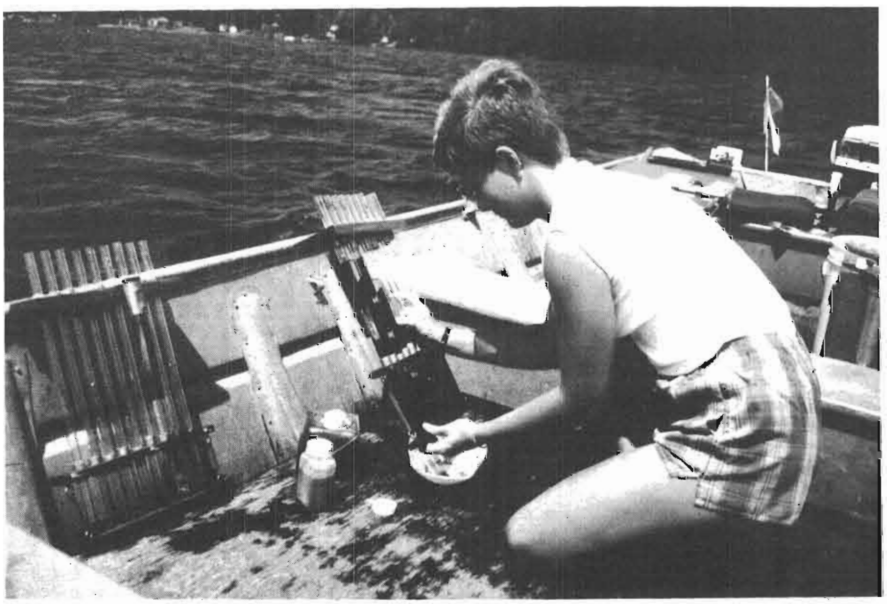
Each sediment sample was split between SLOH, which ran the total mercury analysis (Kopp and McKee 1979), and the University of Wisconsin Soils and Plant Analysis Lab (UWSPAL). All other sediment tests for the elements tested, except for Kjeldahl nitrogen and percent ignition loss (volatile solids), were run by UWSPAL using Inductively Coupled Plasma Emission Spectrometry (ICP).



Scuba diver with samplers for collecting the surface layer of bottom sediments.

Fish

Walleye from most of the 43 study lakes were collected by district fish management field crews in 1985 and 1986 as part of the DNR fish mercury advisory program. In addition, fish were collected from approximately 20% of the lakes by DNR Bureau of Research personnel in the fall of 1986. The fish were weighed and measured in the field, wrapped in foil, and frozen whole until processed at the DNR fish grinding lab operated by the Bureau of Water Resources Management. Scaled, skin-on fillets were ground twice using a stainless steel Hobart tissue grinder. This mash was put in small glass bottles and stored at -5 C until analysis. Total mercury was determined at SLOH by the flameless cold vapor atomic absorption technique (Kopp and McKee 1979).



Compositing sediment samples.

DATA ANALYSIS

Water Chemistry Parameters

Mean annual values for conductivity, total alkalinity, calcium, and color were calculated for each lake using seasonal weighting factors. We felt that these mean values provided a better "characteristic value" for statistical analysis and modeling than a value based on a single sampling. A mean pH for each sampling date was calculated using the vertical profile pH data converted to hydrogen ion concentrations and applying volumetric weighting factors derived from hydrographic maps. Seasonal weighting factors were then used to calculate mean annual pH from each sampling date's mean pH value. Characteristic lake values for Secchi depth, chlorophyll-*a*, and total phosphorus as measures of lake productivity were calculated from the two summer samplings.

Seasonal weighting factors for summer stratification, spring and fall turnover, and winter ice cover were based on mean season lengths for the regions of Wisconsin where the study lakes were located. These lakes fell into three climatic regions: southern, northeastern, and northwestern (Lillie and Mason 1983). The ice cover in northern Wisconsin lasts about two months longer than it does in southern Wisconsin (R. Lillie, G. Quinn, and G. Wegner; Wis. Dep. Nat. Resour.; pers. comm. 1986). Mean ice-in dates for northern and southern Wisconsin were estimated at 1 November and 1 December, respectively. Mean ice-out dates were estimated at 1 May and 1 April for the northern and southern regions. The length of summer stratification was estimated from lake monitoring data collected over a 14-year period by the DNR Bureau of Research (R. Lillie and J. Mason, Wis. Dep. Nat. Resour., pers. comm. 1986). Using these dates and growing season data (Finley 1976), seasonal weighting factors were derived (Table 1) and used to calculate mean annual values for the water chemistry parameters.

Mean lake sediment values for ignition loss, total mercury, nitrogen, phosphorus, and other elements were calculated. Sediments in the depositional zone of the deeper lakes (the region below the thermocline) were often different from sediments in the shallower zones where resuspension can occur throughout the open water season. Because of differences in lake morphometry, the relative area of the depositional zone varied considerably, even among lakes with similar maximum depths. Mean-weighted sediment values were used because the lake sediments are possible sites for binding, bacterial transformations, and volatilization of mercury. These values were calculated in the following way. Each lake was divided into thermal stratification levels based on summer temperature profiles. The percentage of lake bottom in each stratification level was determined by planimetry. Each sediment value was then weighted by the percentage of the lake bottom it represented, and a mean areal sediment value was calculated. Deep hole values were the samples collected in the deepest part of the depositional zone.

Walleye Mercury Concentration

Regression analysis of walleye mercury on length was performed for each lake where enough walleyes had been collected. The mercury concentration for a 17-inch walleye was determined from the regression line equation. This length was selected somewhat subjectively, considering three factors: the length of walleyes from this study, the mean length of walleyes from the mercury testing study conducted by the DNR Bureau of Fisheries Management from 1972 to present, and the average length of walleyes caught by anglers in Wisconsin. The mercury concentration of the 17-inch walleye was called the lake fish mercury concentration and was used as the standardized dependent variable in appropriate analyses. Of the original 43 lakes, 5 did not yield any walleyes. Seven more lakes yielded either only 2 fish or fish of insufficient length variation to generate a regression line to determine the mercury in a 17-inch walleye. Each of the remaining 31 lakes was given a lake fish mercury concentration based on the above regression analyses.

Model Adjustment

Hakanson's (1980) model is based on the mercury content of a 1-kg pike. We modified the model for testing on Wisconsin walleye. A 1-kg northern pike is typically longer and younger than a 1-kg walleye because these species grow at different rates (Mackenthun 1948). Pike and walleye also vary in feeding and mercury assimilation (Mathers and Johansen 1985). In addition, older fish accumulate more mercury. To account for such differences, we adjusted the model as follows. A 1-kg pike from Wisconsin waters is approximately 22 inches long (Van Engel 1940). From length-weight relationships of walleyes from both northern and southern Wisconsin lakes in this study, we determined that a 1-kg walleye was approximately 18 inches long. Using the results of a study of northeastern Minnesota lakes (Helwig and Heiskary 1985), we calculated the proportional difference between the mercury concentrations in a 1-kg (22-inch) pike and a 1-kg (18-inch) walleye. The predicted mercury values generated from Hakanson's model were then adjusted by this proportion so that the model could be tested more accurately. These predicted mercury values were compared to the mercury concentration for a 1-kg (18-inch) walleye, which was determined from the same regression line equation that was used to determine the mercury concentration for a 17-inch walleye.

State Dataset

To test a water chemistry model derived from the mercury study lakes, an independent dataset was necessary. We obtained water chemistry data from 80 lakes throughout the state. Sources of data included the original data files from Lillie and Mason (1983), Glass (1984), Storet System, and regional limnologists. Several chlorophyll-*a* values were calculated from summer Secchi disc values using regression equations from Lillie and Mason (1983). All alkalinity measurements were converted to µeq/L. Different analysis techniques for alkalinity created potential biases. Lillie and Mason (1980) compared methodologies from their dataset with those from more recent samplings (Glass 1984) and found

TABLE 1. *Seasonal weighting factors for calculating the mean annual values of lake water chemistry parameters.*

	Number of Months			
	Winter	Spring	Summer	Autumn
Southern Wisconsin	4.0	1.5	4.5	2.0
Northeastern Wisconsin	6.0	1.5	2.5	2.0
Northwestern Wisconsin	5.0	1.5	3.5	2.0

Preparation of walleyes for mercury testing.

that a correction factor was necessary to equalize values. The correction was calculated for these data. If methodological information was not available, no correction was made.

STATISTICAL ANALYSIS

Computing was done with SAS (Statistical Analysis System Version 5.16, SAS Institute 1986). Procedures included simple linear regression, Spearman rank and Pearson correlations, Analysis of Variance (ANOVA) with Bonferroni multiple comparisons, two-sample *t*-tests, and the *F*-test for homogeneity of variance. A form of the two-sample *t*-test that is valid for unequal variances was used whenever the *F*-test showed a significant difference between the variances of the two groups being compared.

Log transformations were used when necessary to stabilize the variance of dependent variables. Walleye mercury concentrations were log transformed for the regressions on lake water chemistry parameters. We conducted ANOVAs comparing mercury concentrations among water chemistry categories on averages for each lake of log-transformed mercury concentrations. Because the number of walleyes collected was different for each lake, we computed averages to give each lake equal weight in the ANOVA and to ensure correct calculation of the error term for comparisons among lake groups.

RESULTS AND DISCUSSION

Two hundred thirty-one (231) walleyes were collected from 38 of the 43 lakes sampled in our study (Append. Table 1). The median length of all walleyes was 17.7 inches; length class distribution and frequencies are shown in Table 2. Almost one half (45%) of the test fish contained more than the Wisconsin standard of 0.5 μg Hg/g wet weight (0.5 ppm) (Table 2). The percentage of contaminated fish was considerably greater in the ≥20.0-inch length class (78%) than in the two smaller length classes (10% and 38%, respectively). This result supports the reported effect of size on mercury contamination (Kleinert and Degurse 1972, Phillips et al. 1980).

Mercury concentrations in individual walleyes ranged from 0.04 μg/g to 2.8 μg/g wet weight (Table 3). Mean mercury concentrations increased with increasing length class; the mean mercury concentration for the largest length class was above the Wisconsin standard of 0.5 μg/g. All differences between length classes were significantly different from zero, based on Bonferroni multiple comparisons of log-transformed mercury concentrations ($\alpha = 0.05$) (Table 3). This relationship between walleye mercury concentration and length was also examined using simple linear regression. Mercury concentration increased with length ($R^2 = 0.37$), as did the variance about the regression line. Regression of log-transformed mercury concentrations on length resulted in the same R^2 value and F statistic, although the variance was stabilized. While these analyses indicate that mercury concentration increases with fish length, they do not consider the fact that the real experimental unit is the lake, and that the relationship of mercury concentration to length may vary among lakes.

In their study of northern Minnesota lakes, Helwig and Heiskary (1985) did not find as strong a relationship between length and mercury concentration in walleyes as we did. Some of their

TABLE 2. *Length class distribution of walleyes collected from mercury study lakes.*

Length Inches	(mm)	Frequency	% Total	No. Fish ≥0.5 μg Hg/g
<15.0	(<381)	48	21	5(10%)
15.0-19.9	(381-507)	110	48	42(38%)
≥20.0	(≥508)	73	31	56(78%)
Total		231	100	103(45%)

TABLE 3. *Walleye mercury values for length classes of walleyes from mercury study lakes.*

Length Class (inches)	Hg (μg/g) Range	Mean	SD	Sig. Comp.*	n**
<15.0	0.04-1.0	0.31	0.19	A	48
15.0-19.9	0.07-1.8	0.49	0.35	B	110
≥20.0	0.25-2.8	1.02	0.60	C	73

*Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$.

**n refers to number of fish.

samples, however, were composites of several fish, which may have masked that relationship. Wiener (1983) found greater predictability of length on mercury concentration than we did, though his samples were from a smaller number of lakes with low pH. Because a wide variety of lake types was sampled in our study, differences in walleye growth and mercury accumulation among lakes probably accounted for some lack of fit.

Growth data from northern and southern Wisconsin lakes indicated that a walleye from a northern lake was one-half to one year older than a walleye of similar length from a southern lake (Fig. 1). Tomlinson et al. (1980) suggested that slower growth would result in higher mercury levels. Even if the mercury uptake rate remained the same, the amount of mercury per body weight would increase with a slower growth rate because mercury uptake is so rapid compared to its release. The effect of growth and mercury accumulation could not be determined directly for our walleye because their ages had not been calculated. However, the relationship between mercury concentration and length was examined for individual northern and southern lakes to minimize potential differences in growth and uptake mechanisms. The mean slopes for both the northern and southern lakes were compared with a t-test and were not significantly different.

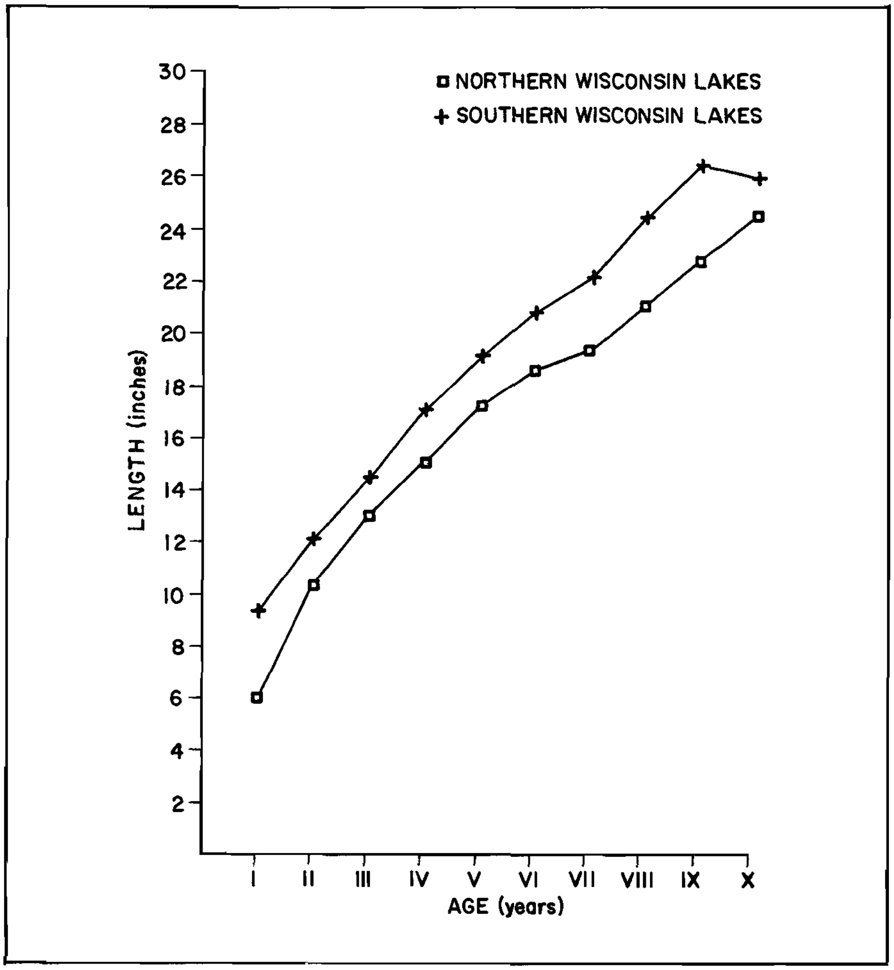


FIGURE 1. Average growth rates of walleyes from northern and southern Wisconsin lakes. (Northern lakes data from H. Snow, Wis. Dep. Nat. Resour., unpubl. data, 1986. Southern lakes data from Druckenmiller 1972.)

WALLEYE MERCURY RELATED TO WATER CHEMISTRY CHARACTERISTICS

The 43 lakes selected for this study are shown in Figure 2. Figure 3 illustrates the distribution of study lakes by water chemistry and morphometric characteristics. Acid-sensitive, soft-water lakes and well-buffered, hard-water lakes are evenly represented in the dataset. Table 4 summarizes water chemistry analyses of these lakes and includes each lake's mercury concentration for a 17-inch walleye, which was calculated for each lake from the regression model of mercury on fish length. Actual seasonal values are reported in Appendix Table 2.

We used simple linear regression to investigate the relationship between each lake parameter and walleye mercury concentration. A logarithmic transformation of the dependent variable, fish mercury concentration, provided a better fit as determined by the R^2 value and residual plots. Several independent variables were log transformed because their relationship to log mercury concentration was more nearly linear after transformation.

The results of these regressions are reported as correlation coefficients, which indicate the strength of the positive or negative relationship of each parameter to walleye mercury levels (Table 5). Two general lake characteristics were strongly related to walleye mercury concentration. The first was the ionic strength of the lake water, determined by pH, alkalinity, calcium concentration, and conductivity. Decreasing values of these parameters were associated with increasing concentrations of fish mercury. These parameters also separate the hard-water and soft-water lakes and, as we expected, correlated highly with each other (Table 6). The second characteristic was lake productivity, measured as chlorophyll-*a*. This parameter had a significant negative relationship with mercury concentrations in walleyes, which supports D'Itri et al.'s (1971) finding that unproductive lakes contained more highly contaminated fish. However, neither total phosphorus nor Secchi depth were good predictors of fish mercury levels. Many of northern Wisconsin's soft-water lakes also are unproductive, but the correlation of chlorophyll-*a* to ionic condition was only 0.29-0.38 (Table 6). Both lake area and depth also showed significant negative relationships with fish mercury concentrations, but the correlation coefficients (r) were low. Although not one of the listed parameters alone was a particularly good predictor of fish mercury, these analyses did indicate the relative importance of the many lake parameters and suggested those that should be examined in more detail.

To investigate more closely the relationship between mercury concentration and lake chemistry, the lakes were divided into categories for each of several water chemistry parameters. These categories reflect the distinction between the soft-water lakes of northern Wisconsin and the hard-water lakes of southern Wisconsin. The ANOVAs with Bonferroni multiple comparisons were done in the same way for all water chemistry parameters. In each case the

LAKE	No.	COUNTY
AMNICON	9	DOUGLAS
BASS	14	PRICE
BIG MUSKELLUNGE	15	VILAS
BUTTERNUT	27	FOREST
CEDAR	1	POLK
CLARK	32	DOOR
CLEAR	25	LANGLADE
CRYSTAL	36	SHEBOYGAN
DELAVAN	42	WALWORTH
DEVILS	37	SAUK
DOWLING	10	DOUGLAS
EMILY	29	FLORENCE
FRANKLIN	20	ONEIDA
GRINDSTONE	7	SAWYER
JAG	16	VILAS
JOYCE	17	VILAS
LITTLE ARBOR VITAE	18	VILAS
LITTLE GREEN	35	GREEN LAKE
LONG	21	ONEIDA
LOST	30	FLORENCE
LOWER BASS	26	LANGLADE
METONGA	28	FOREST
MONONA	39	DANE
NOQUEBAY	31	MARINETTE
NORTH TWO	22	ONEIDA
PIKE	38	WASHINGTON
PINE	41	WAUKESHA
ROCK	40	JEFFERSON
ROUND	3	CHIPPEWA
SAND	23	ONEIDA
SAND	2	POLK
SAND	8	SAWYER
SCOTT	4	BARRON
SHAWANO	33	SHAWANO
SHELL	5	WASHBURN
SILVER (BIG)	34	WAUSHARA
SISKIWIT	11	BAYFIELD
SUGAR CAMP	24	ONEIDA
TAHKODAH	12	BAYFIELD
TWENTY-SIX	6	BURNETT
TWIN BEAR	13	BAYFIELD
WHITE BIRCH	19	VILAS
WIND	43	RACINE

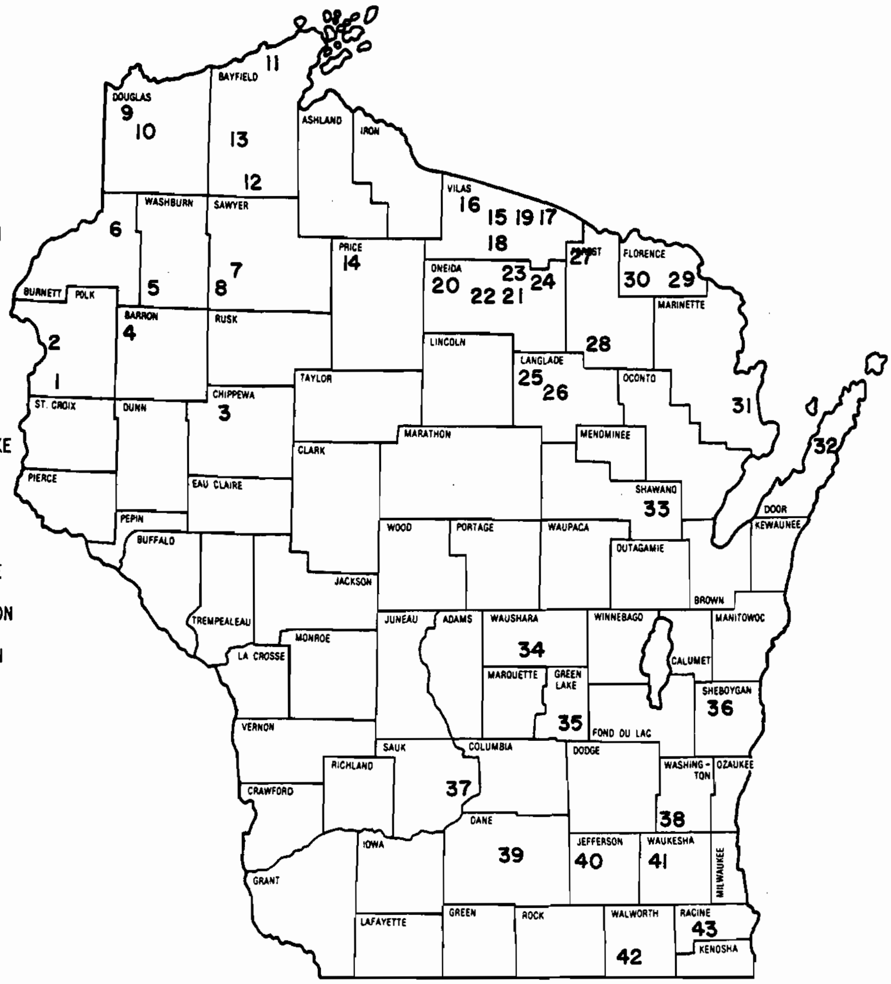


FIGURE 2. Names and locations of lakes sampled.

mean mercury concentration was calculated for all fish in each lake. The mean values were then used in the analyses for all lengths. Because walleye mercury concentration increases as fish length increases, the analyses were also conducted separately for each of three length classes. For this purpose, mean mercury concentrations were calculated for each length class in each lake. Because all length classes were not represented in every lake, the number of lakes in each water chemistry category may be less than the total possible. These mean values were then used in analyses done separately by length class. Means and standard deviations reported in the following tables were based on untransformed mean lake mercury concentrations. Because the standard deviation tends to increase as the mean increases, the ANOVAs and multiple comparisons (α = 0.05) were carried out on means of log-transformed values.

Four pH categories were designated: <6.0, 6.0-6.9, 7.0-7.9, and ≥8.0 (Table 7). For walleyes of all lengths the ANOVAs showed a significant difference in mean mercury concentration among the pH categories ($P < 0.0001$). Lakes with pH <6.0 had mean walleye mercury concentrations significantly greater than lakes with higher pH values. Mean walleye mercury concentrations in the low pH lakes (<7.0) were greater than the Wisconsin allowable concentration of 0.5 μg/g.

Mean mercury concentrations in walleyes <15.0 inches differed significantly between the highest and lowest pH categories, with intermediate pH categories having intermediate mean mercury concentrations. The same trend for mean walleye mercury concentrations to increase as pH decreased was apparent for the two larger size classes of fish as well, although the pattern of significant pairwise comparisons varied somewhat.

The mean mercury concentration exceeded the Wisconsin standard for all walleye length classes in lakes with pH values <6.0. The mean for fish between 15.0 and 19.9 inches also exceeded the Wisconsin standard in lakes with pH of 6.0-6.9. In the largest length class (≥20.0 inches), the mean exceeded the 0.5 μg/g standard in all lake pH categories and exceeded the FDA limit of 1.0 μg/g in lakes with pH <7.0. The sample size of lakes with pH <6.0 and fish <15.0 inches was small enough to warrant caution in interpreting results. However, further analysis discussed below indicates that these results probably are reliable. Apparently, even small walleyes are at risk of accumulating concentrations of mercury above the Wisconsin standard in low pH lakes. Walleyes ≥20.0 inches may become contaminated at all pH levels, even in calcareous lakes where acidification is not an issue.

A similar analysis was performed for three alkalinity categories: <200, 200-999, and ≥1,000 μeq/L (Table 8). Mean mercury concentrations for walleyes of all lengths were 1.16, 0.49, and 0.35 μg/g for the above alkalinity categories. The mean mercury concentra-

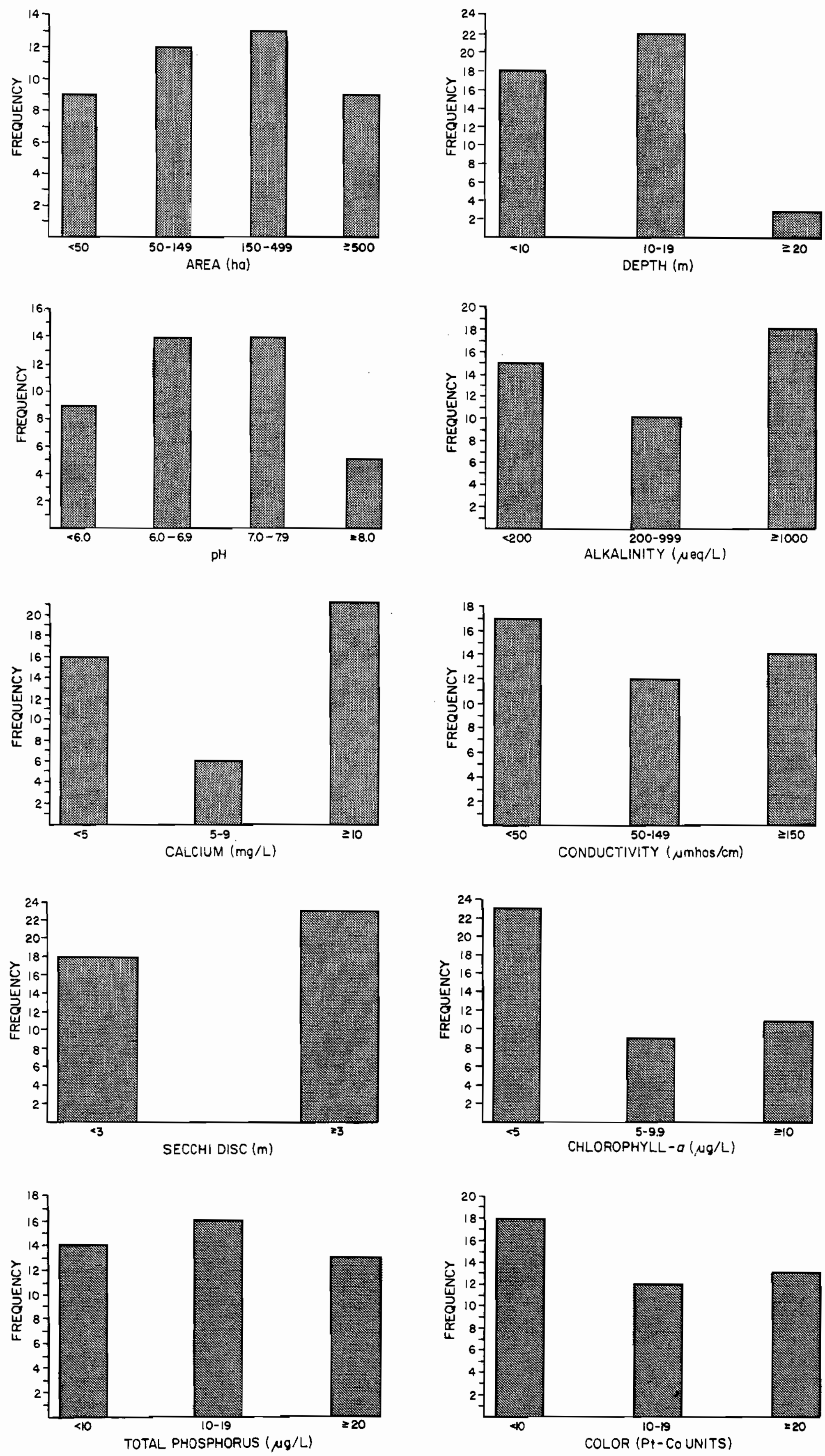


FIGURE 3. Frequency distribution for lake parameters of lakes sampled.

TABLE 4. *Mean annual values for water chemistry parameters of mercury study lakes.*

Lake	Lake Number	County	Area (ha)	Depth (m)	Secchi (m)	Color (Pt-Co)	Conduct. (μmhos/cm)	pH	Alk. (μeq/L)	Ca (mg/L)	Tot. P (μg/L)	Chl-*a* (μg/L)	Fish Hg* (μg/g)
Amnicon	9	Douglas	172	9.5	2.7	37	155	6.7	403	6	16	5.0	0.73
Bass	14	Price	34	14.0	3.8	37	26	5.7	51	2	8	3.0	1.24
Big Muskellunge	15	Vilas	376	21.4	5.9	5	49	6.8	364	6	8	2.0	0.42
Butternut	27	Forest	523	12.8	5.7	5	87	7.3	753	10	8	2.5	0.17
Cedar	1	Polk	448	8.5	2.1	13	227	7.4	2,182	30	92	31.0	0.23
Clark	32	Door	351	7.6	2.0	18	399	8.1	4,073	42	6	2.0	0.29
Clear	25	Langlade	36	7.0	4.2	24	19	4.7	-3	1	12	4.0	—
Crystal	36	Sheboygan	62	18.6	4.1	5	361	8.1	3,030	30	8	2.0	—
Delavan	42	Walworth	838	17.1	1.2	12	665	8.1	3,387	38	104	59.0	0.06
Devils	37	Sauk	151	13.1	8.5	7	76	6.8	449	7	12	8.0	0.87
Dowling	10	Douglas	62	4.0	1.5	84	42	6.5	341	5	38	7.5	0.62
Emily	29	Florence	41	13.1	3.1	8	359	7.3	1,692	21	9	3.0	0.21
Franklin	20	Oneida	65	7.6	6.1	5	19	5.6	29	2	8	2.0	—
Grindstone	7	Sawyer	1,259	18.3	4.7	8	106	7.3	973	13	8	3.5	0.17
Jag	16	Vilas	64	4.3	3.5	10	22	5.7	35	2	14	2.0	0.67
Joyce	17	Vilas	12	10.1	6.4	5	19	5.4	11	1	10	2.5	—
Little Arbor Vitae	18	Vilas	216	9.8	1.7	12	99	6.8	1,085	14	54	42.5	0.09
Little Green	35	Green Lake	189	8.5	1.4	20	362	7.7	3,172	36	245	43.0	0.28
Long	21	Oneida	46	9.5	7.8	5	16	5.0	17	1	8	2.5	0.33
Lost	30	Florence	36	13.7	5.0	5	20	5.8	16	2	8	2.0	—
Lower Bass	26	Langlade	36	5.8	4.9	15	16	5.4	18	1	10	3.0	—
Metonga	28	Forest	806	24.1	4.8	6	198	7.3	1,761	21	16	6.0	0.24
Monona	39	Dane	1,350	19.5	1.8	10	421	8.0	3,265	33	74	26.0	0.36
Noquebay	31	Marinette	975	15.6	3.4	38	273	7.6	2,738	37	13	3.5	0.61
North Two	22	Oneida	59	14.3	5.7	5	19	6.3	62	2	7	1.5	—
Pike	38	Washington	211	13.7	1.8	16	569	8.0	3,884	41	18	7.5	0.26
Pine	41	Waukesha	284	25.9	3.6	8	336	8.0	2,843	28	18	4.0	—
Rock	40	Jefferson	635	17.1	2.4	10	545	7.9	3,599	39	14	6.5	0.27
Round	3	Chippewa	87	5.5	2.0	20	15	6.0	55	2	21	5.5	0.48
Sand	23	Oneida	218	7.6	1.8	100	46	6.3	253	4	28	7.5	0.66
Sand	2	Polk	76	17.7	1.6	11	147	7.1	1,144	16	25	15.5	0.26
Sand	8	Sawyer	376	15.2	2.5	24	74	6.8	539	9	31	17.5	0.37
Scott	4	Barron	33	7.9	1.5	30	36	6.1	131	2	29	14.5	1.02
Shawano	33	Shawano	1,500	11.0	1.8	40	343	6.7	1,984	25	24	10.0	0.35
Shell	5	Washburn	1,044	4.0	3.0	6	79	7.1	155	3	16	11.0	0.57
Silver, Big	34	Waushara	139	15.2	4.3	7	246	7.9	2,248	23	10	3.0	0.51
Siskiwit	11	Bayfield	134	4.0	0.9	128	16	6.0	74	2	30	8.5	0.66
Sugar Camp	24	Oneida	221	11.6	5.7	2	25	5.2	5	2	9	3.0	—
Tahkodah	12	Bayfield	62	5.5	3.3	6	17	6.0	44	1	12	4.0	1.83
Twenty-Six	6	Burnett	93	13.7	3.7	10	155	7.0	946	14	10	3.5	—
Twin Bear	13	Bayfield	70	18.0	5.7	8	118	7.1	1,093	16	6	1.5	0.46
White Birch	19	Vilas	47	8.2	5.0	8	62	6.6	533	8	12	4.0	0.50
Wind	43	Racine	379	14.3	1.4	35	682	7.5	3,170	47	45	22.5	—

*Mercury concentration for a 17-inch walleye calculated from a regression model of mercury on fish length.

tions in lakes with alkalinities <200 μeq/L were significantly greater than those in the other alkalinity categories, and those in alkalinity categories <1,000 μeq/L were at or higher than the Wisconsin limit.

Analysis of the three length classes produced results indicating the same trend of increased mercury concentrations with increased length and decreased lake ionic content, as was found in the pH analysis. Mean mercury concentrations differed significantly between the lowest and highest alkalinity categories for all length classes, with the intermediate alkalinity category having an intermediate mercury concentration (Table 8). Fish ⩾20.0 inches exceeded the Wisconsin standard of 0.5 μg/g mercury in all alkalinity categories and the FDA standard of

TABLE 5. *Pearson correlation of log-transformed walleye mercury values to individual lake parameters.*

Parameter	*r*	*P > F*
log alk.	-0.59	0.0003
pH	-0.55	0.0012
log Ca	-0.64	0.0001
Color	0.31	0.0810
log conduct.	-0.58	0.0005
Secchi depth	0.14	0.4300
Tot. P	-0.31	0.0860
log area	-0.45	0.0097
Depth	-0.39	0.0290
Chl-*a*	-0.57	0.0006

TABLE 6. *Spearman rank correlation of water chemistry and morphometry parameters, n = 43.*

	Alk.	pH	Ca	Color	Conduct.	Secchi	Tot. P	Area	Depth
pH	0.95*	—	—	—	—	—	—	—	—
	<0.01**	—	—	—	—	—	—	—	—
Ca	0.98	0.93	—	—	—	—	—	—	—
	<0.01	<0.01	—	—	—	—	—	—	—
Color	0.22	0.06	0.20	—	—	—	—	—	—
	0.16	0.70	0.19	—	—	—	—	—	—
Conduct.	0.94	0.91	0.96	0.17	—	—	—	—	—
	<0.01	<0.01	<0.01	0.27	—	—	—	—	—
Secchi	-0.47	-0.36	-0.43	-0.75	-0.41	—	—	—	—
	<0.01	0.02	<0.01	<0.01	<0.01	—	—	—	—
Tot. P	0.32	0.22	0.29	0.59	0.28	-0.79	—	—	—
	0.04	0.16	0.06	<0.01	0.07	<0.01	—	—	—
Area	0.61	0.61	0.64	0.11	0.60	-0.29	0.37	—	—
	<0.01	<0.01	<0.01	0.47	<0.01	0.06	0.02	—	—
Depth	0.52	0.56	0.54	-0.29	0.55	0.18	-0.15	0.36	—
	<0.01	<0.01	<0.01	0.06	<0.01	0.24	0.34	0.02	—
Chl-*a*	0.38	0.29	0.35	0.57	0.36	-0.81	0.93	0.42	-0.08
	0.01	0.06	0.02	<0.01	0.02	<0.01	<0.01	<0.01	0.62

*Spearman correlation coefficients.
**Probability of obtaining a larger value (in absolute value) of *r* under the null hypothesis that the true value of *r* is zero.

TABLE 7. *Mean walleye mercury values for length classes and lake pH categories using the mercury study lakes.*

	All Lengths			<15.0 Inches			15.0-19.9 Inches			≥20.0 Inches		
pH	Mean Hg (μg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (μg/g)	(SD,n)	Sig. Comp.	Mean Hg (μg/g)	(SD,n)	Sig. Comp.	Mean Hg (μg/g)	(SD,n)	Sig. Comp.
<6.0	1.43	(0.26, 6)	A	0.53	(0.16, 2)	A	0.95	(0.37, 4)	A	1.74	(0.25, 6)	A
6.0-6.9	0.67	(0.39,14)	B	0.39	(0.17, 9)	AB	0.65	(0.43,13)	AB	1.07	(0.69,12)	AB
7.0-7.9	0.36	(0.18,13)	B	0.24	(0.11, 6)	AB	0.33	(0.16,13)	BC	0.64	(0.36, 8)	B
≥8.0	0.35	(0.15, 5)	B	0.16	(0.05, 5)	B	0.22	(0.15, 3)	C	0.55	(0.11, 4)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

TABLE 8. *Mean walleye mercury values for length classes and lake alkalinity categories using the mercury study lakes.*

	All Lengths			<15.0 Inches			15.0-19.9 Inches			≥20.0 Inches		
Alkalinity (μeq/L)	Mean Hg (μg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (μg/g)	(SD,n)	Sig. Comp.	Mean Hg (μg/g)	(SD,n)	Sig. Comp.	Mean Hg (μg/g)	(SD,n)	Sig. Comp.
<200	1.16	(0.46,12)	A	0.40	(0.16, 5)	A	0.90	(0.43,10)	A	1.51	(0.41,11)	A
200-999	0.49	(0.23, 9)	B	0.41	(0.19, 7)	A	0.47	(0.27, 8)	B	1.02	(0.83, 7)	B
≥1,000	0.35	(0.17,17)	B	0.19	(0.09,10)	B	0.30	(0.16,15)	B	0.58	(0.29,12)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

1.0 μg/g for alkalinities <1,000 μeq/L. Medium-sized walleyes 15.0-19.9 inches had mean mercury concentrations >0.5 μg/g in lakes with alkalinities <200 μeq/L. None of the mean mercury concentrations in the three alkalinity ranges exceeded the Wisconsin standard for walleyes <15.0 inches.

Calcium concentration and conductivity were related to fish mercury concentrations in much the same way as were pH and alkalinity (Tables 9 and 10). Because these four water chemistry parameters were highly correlated, we expected to find similar results.

When walleyes of all lengths were considered, we found significant differences between mean mercury concentrations in lakes with calcium concentrations <5 mg/L and those with greater concentrations (Table 9). Lakes with calcium concentrations <10 mg/L had mean fish mercury concentrations above the Wisconsin standard. Lakes with conductivities <50 μmhos/cm had a mean fish mercury concentration exceeding the 0.5 μg/g limit, and lakes with conductivity values <50 μmhos/cm had a mean fish mercury concentration that was significantly different from lakes with higher conductivity values (Table 10). For both of these water chemistry parameters the mean mercury concentrations for fish >20.0 inches from all calcium and conductivity categories exceeded the Wisconsin standard. In lakes with calcium concentrations <10 mg/L or conductivities <50 μmhos/cm, medium-sized walleyes (15.0-19.9 inches) had mean mercury values that exceeded the Wisconsin standard, and large-sized walleyes (⩾20.0 inches) had values that exceeded the FDA standard (Tables 9 and 10).

Mean mercury concentrations in walleyes decreased as chlorophyll-*a* increased (categories were <5, 5-9, and ⩾10 μg/L). For all fish length classes combined there were significant differences between lakes with chlorophyll-*a* concentrations <5 μg/L and those lakes with concentrations ⩾10 μg/L (Table 11). Mean mercury concentrations were greater than 0.5 μg/g in lakes with chlorophyll-*a* concentrations <10 μg/L. There were no significant differences between any pairs of mean mercury concentrations in any of the analyses done separately by length category, although in all categories mean mercury concentrations increased as chlorophyll-*a* decreased. For walleyes in the 15.0-19.9 inch length category, the mean mercury concentration exceeded the Wisconsin standard in the least productive lakes. Mean mercury concentrations for fish ⩾20.0 inches exceeded the Wisconsin standard in all chlorophyll-*a* categories. The FDA limit was exceeded for walleyes ⩾20.0 inches in lakes with <10 μg/L chlorophyll-*a*.

In Wisconsin many walleyes that have been tested for mercury have exceeded the Wisconsin standard. The results of this study indicate that lakes with low values of pH, alkalinity, calcium, conductivity, and chlorophyll-*a* have the most highly contaminated walleyes. Fish length is clearly an important factor. The average length of walleye caught and consumed by the Wisconsin angler is approximately 17 inches. If we examine the length class in which such walleye are found, we can see that lakes with pH <7.0, alkalinities <1,000 μeq/L, calcium concentrations <10 mg/L, conductivities <50 μmhos/cm, and chlorophyll-*a* concentrations <5 μg/L contain walleyes with mean mercury concentrations above the allowable 0.5 μg/g. Mean walleye mercury concentrations were less than the Wisconsin standard for lakes in the successively higher water chemistry categories. However, individual lakes may contain 15.0-19.9 inch walleyes above the allowable limit because of variability among lakes.

WALLEYE MERCURY RELATED TO SEDIMENT CHEMISTRY CHARACTERISTICS

Mercury and Organic Content

The results for sediment mercury and two measures of sediment organic content, ignition loss (**Ig**) and total nitrogen, are presented in Table 12. Both areal and deep hole values are reported because they frequently differ, depending on the morphometry of the lake, and these differences may be important for mercury availability to fish. The actual values used to generate the areal values are reported in Appendix Table 3. All but three lakes had sediment mercury concentrations ⩽0.2 μg/g dry weight. Lake Monona in southern Wisconsin had a very high mid-depth concentration compared with the other lakes, probably because for some years the City of Madison's sewage and industrial effluent was discharged into the lake (Syers et al. 1973). Because of this unusual input the sediment mercury data for Lake Monona were not included in the analysis.

Regression analysis was used to examine the relationship between walleye mercury values and lake sediment characteristics. As with the water chemistry data, a logarithmic transformation was performed on the dependent variable, fish mercury, because of unequal variances. Areal and deep hole sediment mercury concentrations were significant predictors of fish mercury (Table 13), although the *r* values were relatively low.

Konrad (1971) found high mercury concentrations in fish in some areas with high sediment mercury, although the sediments tested had been polluted by point sources. Studies in unpolluted aquatic systems did not find a positive correlation between sediment and fish mercury (Megan 1986, Surma-Aho et al. 1986). The sediment mercury concentrations reported for this study were similar to the background concentrations of 0.01-0.24 μg/g reported for some northern and southern Wisconsin lakes (Syers et al. 1973). A more recent study reported background concentrations of 0.04-0.07 μg/g for another group of northern Wisconsin lakes (Rada et al. 1987). Hakanson (1980) found sediment mercury levels of 0.15 μg/g in central Swedish lakes unpolluted by point sources. The sediments in most Wisconsin lakes are not high in mercury, so that sediment mercury may not be a good indicator of fish mercury in lakes not contaminated from point sources, at least at the level of laboratory detection determined on our samples.

To determine whether sediment characteristics varied as a function of water chemistry, mean sediment mercury concentrations were compared in lakes with pH values above and below 7.0. Only two pH categories were used for this analysis because of sample size restrictions. We used lake pH as a convenient way of dividing the soft-water and hard-water lakes and are not implying that pH directs these processes. The underlying mechanisms are not clear, and other determinants of hard-water and soft-water lakes, such as alkalinity or calcium, also could be used. The *t*-tests showed that the mean sediment mercury concentrations for both areal and deep hole samples were significantly higher in lakes with pH <7.0 than in those with higher pH values (Table 14). The results suggest that mercury input, net methylation rate, or the partitioning of mercury within the lake varies with the pH of the lake.

The values for ignition loss and total nitrogen indicate that our study lakes have moderately organic sediments, with few high or low values (Table 14). Neither sediment total nitrogen nor ignition loss was significantly correlated to walleye mercury concentrations (Table 13). As with sediment mercury concentrations, mean areal and deep hole values for ignition loss and total nitrogen were significantly greater in those lakes with pH <7.0 (Table 14).

Because mercury readily associates with organic matter (Konrad 1972, Thomas and Jacquet 1976, Thanabalasingam and Pickering 1985), the relationship between sediment mercury and organic content was examined. For all lakes the correlations using areal sediment mercury values were significant, although the *r* values were low and ignition loss was a somewhat better predictor than total nitrogen (Table 15). Deep hole values were less correlated.

The relationship between sediment mercury and organic content was different for lakes with pH <7.0 and those with pH ⩾7.0 (Table 15). For the more acidic lakes, the relationship between deep hole mercury concentrations and both ignition loss and total nitrogen was significant, but the *r* value was not high for either parameter. In lakes with higher pH, the relationship was dramatically different. All correlations using areal and deep hole values were significant, though *r* values for the deep hole correlations were higher than those for areal correlations.

Jackson (1980) found that the complexation of mercury with organic matter did not change with decreasing pH, though the incorporation of mercury into the sediments decreased. More mercury presumably remained in the water column and may have been available to fish. Our results suggest that the mercury-organic matter relationship in sediments does change with decreasing pH, though the basis for the change is unclear.

Sediments from lakes with pH <7.0 contained more mercury and organic matter than those from more alkaline lakes. Fish mercury concentrations were also higher, suggesting that perhaps methylation rates were higher in low pH lakes with moderate organic content. Callister and Winfrey (1986) found higher methylation rates in organically enriched sediments of the upper Wisconsin River, as did other researchers working on Canadian waterways (Furutani and Rudd 1980, Rudd and Turner 1983, Bodaly et al. 1984). The latter suggested that in-

TABLE 9. *Mean walleye mercury values for length classes and lake calcium categories using the mercury study lakes.*

	All Lengths			<15.0 Inches			15.0-19.9 Inches			⩾20.0 Inches		
Calcium (mg/L)	Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<5	1.12	(0.47,13)	A	0.41	(0.14, 6)	A	0.85	(0.44,11)	A	1.47	(0.41,12)	A
5-9	0.57	(0.21, 6)	B	0.40	(0.20, 6)	A	0.59	(0.27, 5)	A	1.15	(0.95, 5)	A
⩾10	0.34	(0.16,19)	B	0.19	(0.09,10)	B	0.29	(0.15,17)	B	0.56	(0.29,13)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

TABLE 10. *Mean walleye mercury values for length classes and lake conductivity categories using the mercury study lakes.*

	All Lengths			<15.0 Inches			15.0-19.9 Inches			⩾20.0 Inches		
Conductivity (µmhos/cm)	Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<50	1.07	(0.49,14)	A	0.38	(0.15, 7)	A	0.87	(0.43,11)	A	1.39	(0.47,13)	A
50-149	0.39	(0.22, 9)	B	0.40	(0.21, 5)	A	0.39	(0.27, 9)	B	0.62	(0.37, 5)	B
⩾150	0.39	(0.19,15)	B	0.21	(0.12,10)	A	0.33	(0.17,13)	B	0.79	(0.69,12)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

TABLE 11. *Mean walleye mercury values for length classes and lake chlorophyll-a categories using the mercury study lakes.*

	All Lengths			<15.0 Inches			15.0-19.9 Inches			⩾20.0 Inches		
Chl-*a* (µg/L)	Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<5	0.84	(0.55,19)	A	0.38	(0.21, 9)	A	0.68	(0.46,15)	A	1.15	(0.61,16)	A
5-9	0.53	(0.21, 8)	AB	0.30	(0.13, 7)	A	0.42	(0.19, 8)	A	1.09	(0.78, 8)	A
⩾10	0.37	(0.24,11)	B	0.20	(0.11, 6)	A	0.36	(0.28,10)	A	0.58	(0.24, 6)	A

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

TABLE 12. *Sediment mercury and organic content for areal and deep hole samples from mercury study lakes.*

Lake	Lake Number	County	Tot. Hg (µg/g)	Tot. Hg(D)* (µg/g)	Ig** (%)	Ig(D) (%)	Tot. N (%)	Tot. N(D) (%)
Amnicon	9	Douglas	0.20	0.20	41.1	38.0	1.72	1.64
Bass	14	Price	0.15	0.20	27.3	38.9	1.08	1.60
Big Muskellunge	15	Vilas	0.07	0.10	—	56.0	—	2.73
Butternut	27	Forest	0.07	0.10	15.0	29.4	0.71	1.40
Cedar	1	Polk	0.07	0.05	27.9	24.0	1.35	1.25
Clark	32	Door	0.05	0.05	12.6	11.1	0.53	0.52
Clear	25	Langlade	0.20	0.20	49.2	51.3	1.83	2.01
Crystal	36	Sheboygan	0.10	0.10	30.8	29.3	1.60	1.45
Delavan	42	Walworth	0.05	0.05	12.4	13.9	0.56	0.68
Devils	37	Sauk	0.20	0.20	17.1	23.8	1.02	1.09
Dowling	10	Douglas	0.30	0.30	38.2	38.2	1.56	1.56
Emily	29	Florence	0.12	0.20	8.0	47.5	0.36	2.10
Franklin	20	Oneida	0.10	0.10	21.6	39.8	1.24	1.49
Grindstone	7	Sawyer	0.10	0.10	15.4	35.1	0.78	1.81
Jag	16	Vilas	0.20	0.20	52.9	52.9	2.44	2.44
Joyce	17	Vilas	0.20	0.20	55.5	55.5	2.61	2.61
Little Arbor Vitae	18	Vilas	0.10	0.10	49.8	47.4	2.80	2.63
Little Green	35	Green Lake	0.09	0.05	28.5	32.6	1.40	1.51
Long	21	Oneida	0.14	0.05	59.0	62.0	2.30	2.47
Lost	30	Florence	0.05	0.05	31.8	59.9	1.30	2.71
Lower Bass	26	Langlade	0.10	0.10	62.6	64.2	2.43	2.62
Metonga	28	Forest	0.12	0.10	22.2	36.1	1.20	1.74
Monona	39	Dane	0.28	0.48	10.3	21.2	0.48	0.95
Noquebay	31	Marinette	0.05	0.20	4.1	41.1	0.22	1.97
North Two	22	Oneida	0.08	0.10	22.8	43.6	0.92	1.76
Pike	38	Washington	0.05	0.05	10.4	17.3	0.43	0.71
Pine	41	Waukesha	0.17	0.20	31.6	39.0	1.40	1.75
Rock	40	Jefferson	0.05	0.05	19.4	20.8	0.95	0.98
Round	3	Chippewa	0.20	0.20	47.9	47.9	2.17	2.17
Sand	23	Oneida	0.30	0.30	42.6	42.6	1.34	1.34
Sand	2	Polk	0.09	0.10	13.8	24.2	0.90	1.23
Sand	8	Sawyer	0.20	0.20	37.1	39.2	1.50	1.61
Scott	4	Barron	0.12	0.20	32.0	34.8	1.64	1.84
Shawano	33	Shawano	0.20	0.20	46.9	46.9	2.38	2.38
Shell	5	Washburn	0.07	0.10	15.4	27.5	0.67	1.22
Silver, Big	34	Waushara	0.20	0.20	49.9	47.5	2.50	2.34
Siskiwit	11	Bayfield	0.20	0.20	35.0	35.0	1.10	1.10
Sugar Camp	24	Oneida	0.09	0.10	26.5	28.0	0.55	1.09
Tahkodah	12	Bayfield	0.10	0.10	36.4	36.4	1.70	1.68
Twenty-Six	6	Burnett	0.13	0.20	39.6	41.5	2.00	2.14
Twin Bear	13	Bayfield	0.10	0.10	47.9	43.7	2.30	2.00
White Birch	19	Vilas	0.10	0.10	68.4	68.4	3.89	3.84
Wind	43	Racine	0.05	0.05	20.9	25.8	0.94	1.15

*D signifies deep hole values.
**Ig signifies ignition loss = volatile solids.

creased organic content provided more substrate for the microbes that methylate the mercury.

Knowing the relative amounts of inorganic mercury and organic methylmercury in the sediments and water column would help scientists to understand how changes in the partitioning of available mercury and net methylation rate ultimately affect fish mercury concentrations. In previous studies researchers have found mercury in the water difficult to measure because of its low concentrations. Rapid uptake by the biota and volatilization of elemental and dimethylmercury prevent the accumulation of large quantities of mercury in the water column, though it is not clear how these processes differ between hard-water and soft-water lakes.

Relative proportions of dissolved and particulate organic matter also may be important in determining mercury availability to the biota. Mercury may be more or less available depending on the particular associations it forms with organic matter. Because of the apparent differences in the behavior of sediment mercury, sediment organic matter, and fish mercury in hard and soft waters, a comparative study of such lakes may provide insight into the complex cycling of mercury in lakes.

Other Elements

Table 16 presents the results of sediment analysis for calcium, sulfur, iron, and phosphorus. (Appendix Table 3 contains the values for each depth and the values of other elements not directly used in our analysis.) Areal and deep hole values were fairly similar in our study lakes. We used *t*-tests to determine how these sediment characteristics differed between lakes with high ($\geqslant$7.0) and low ($<$7.0) pH values. Areal and deep hole calcium concentrations, as well as deep hole sulfur concentrations, were significantly different between lake types, with larger concentrations found in lakes with pH $\geqslant$7.0. Mean areal concentrations of phosphorus were significantly greater in low pH lakes, while deep hole concentrations were not statistically different (Table 14).

Mercury binds to sulfur to form the relatively insoluble mercuric sulfide or cinnabar. There was no significant cor-

TABLE 13. *Pearson correlation of log-transformed walleye mercury values to sediment parameters of mercury study lakes.*

Parameter	r	P > F
Tot. Hg	0.43	0.01
Tot. Hg(D)*	0.53	0.004
Ig	0.26	0.14
Ig(D)	0.25	0.17
Tot. N	0.17	0.35
Tot. N(D)	0.12	0.50

*D signifies deep hole values.

TABLE 14. *Sediment characteristics for two lake pH categories of mercury study lakes.*

	pH < 7.0			pH ≥ 7.0			
	Mean	(n)	SD	Mean	(n)	SD	P*
Tot. Hg (μg/g)	0.16	(23)	0.07	0.09	(19)	0.04	0.0006
Tot. Hg(D) (μg/g)**	0.16	(23)	0.07	0.11	(19)	0.06	0.0126
Ig (%)	40.80	(23)	13.60	21.80	(20)	13.00	0.0001
Ig(D) (%)	45.70	(23)	11.60	30.40	(20)	10.90	0.0001
Tot. N (%)	1.80	(23)	0.75	1.06	(20)	0.65	0.0014
Tot. N(D) (%)	2.02	(23)	0.68	1.44	(20)	0.53	0.0034
Ca (mg/g)	4.70	(23)	5.50	26.90	(20)	12.30	0.0001
Ca(D) (mg/g)	5.60	(23)	3.80	74.00	(20)	96.20	0.0049
Fe (mg/g)	31.00	(23)	33.20	20.60	(20)	16.50	0.1947
Fe(D) (mg/g)	33.00	(23)	36.20	27.00	(20)	24.20	0.5205
S (mg/g)	4.80	(23)	2.50	6.10	(20)	3.10	0.1595
S(D) (mg/g)	5.20	(23)	1.90	8.60	(20)	5.30	0.0113
P (mg/g)	2.30	(23)	1.40	1.50	(20)	0.80	0.0249
P(D) (mg/g)	2.90	(23)	2.30	2.40	(20)	1.80	0.4291

**t*-test to compare lake pH categories.
**D signifies deep hole values.

TABLE 15. *Pearson correlation of sediment mercury to sediment organic content of mercury study lakes.*

	All Lakes		pH < 7.0		pH ≥ 7.0	
	r	P > F	r	P > F	r	P > F
Tot. Hg on Ig	0.49	0.001	0.11	0.61	0.66	0.0020
Tot. Hg(D)* on Ig(D)	0.27	0.090	-0.41	0.05	0.82	0.0001
Tot. Hg on Tot. N	0.36	0.020	-0.04	0.87	0.68	0.0020
Tot. Hg(D) on Tot. N(D)	0.16	0.300	-0.43	0.04	0.81	0.0001

*D signifies deep hole values.

relation, however, between sediment mercury and sulfur when all lakes were examined together. Considering only lakes with pH <7.0, the correlation for deep hole values was significant, though the *r* value was not high (Table 17). Furutani and Rudd (1980) suggested that the high methylation rates that they observed in sulfide-rich sediments might be due to high iron concentrations because the iron will bind to the sulfide, making it unavailable to mercury. In our study lakes the correlation between sulfur and iron was not significant (Table 18).

PREDICTIVE MODELS OF WALLEYE MERCURY

Hakanson's Model

The three parameters used in Hakanson's (1980) model to predict fish mercury concentrations were lake pH, sediment mercury concentration, and bioproductivity index (BPI) (Table 19). The latter is a direct measure of lake productivity based on the relationship between total nitrogen and ignition loss of the sediment. Because of Hakanson's restrictions on the use of nitrogen and ignition loss sediment data, we generated BPI by Hakanson's indirect method, using lake water total phosphorus values.

Walleye mercury values for the Wisconsin lakes were predicted using both areal and deep hole sediment values in the model (Table 19). The correlation coefficient (*r*) using the areal values in the model was 0.55. Testing the model using deep hole values produced a similar correlation (0.56).

Figure 4 shows one outlier in the dataset, Lake Tahkodah. If this lake were omitted, the correlation coefficient would increase to 0.74 when the areal sediment mercury values were used and to 0.76 when the deep hole values were used. Hakanson (1980) reported a correlation coefficient of 0.79 in his test of the model. However, we know of nothing unusual about Lake Tahkodah that would account for such high mercury concentrations in its walleyes, and therefore we have no reason to omit this lake from the analysis.

Of the 31 Wisconsin lakes tested with Hakanson's (1980) model, 12 had predicted mercury concentrations that were higher than the actual walleye mercury values. The model had been adjusted for the fact that a 1-kg walleye would be older and would have accumulated more mercury than the 1-kg northern pike on which the model was based. An adjustment for the differences in rate of mercury uptake and assimilation by length for northern and southern Wisconsin walleyes would also be useful. Another potential source of error in applying this model to our dataset is the BPI, which according to Hakanson was most accurate for lakes of low organic content. The relationship between ignition loss and total nitrogen was less clear in lakes with greater than 30% organic content in the sediment (Hakanson 1984). Our dataset contained some lakes with sediment organic content over 30%. In addition to the above concerns, sediment mercury concentrations did not vary much among lakes, and the earlier regression of sediment mercury and fish mercury showed a poor relationship.

TABLE 16. *Sediment calcium, sulfur, iron, and phosphorus of mercury study lakes.*

		(mg/g)							
Lake	County	Ca	Ca(D)*	S	S(D)	Fe	Fe(D)	P	P(D)
Amnicon	Douglas	8.5	6.9	3.2	3.3	107.4	107.5	3.8	3.9
Bass	Price	5.1	5.4	2.7	4.6	13.2	15.4	1.3	1.8
Big Muskellunge	Vilas	—	7.1	—	9.3	—	12.8	—	2.8
Butternut	Forest	4.9	6.6	1.2	2.3	40.5	85.5	2.2	4.1
Cedar	Polk	3.9	50.7	5.1	5.1	18.7	17.8	1.9	2.4
Clark	Door	282.3	316.9	6.3	6.5	3.0	2.6	0.3	0.2
Clear	Langlade	3.3	3.3	3.7	4.0	13.2	11.3	1.5	1.6
Crystal	Sheboygan	80.6	70.9	11.0	8.8	11.6	10.4	1.5	1.7
Delavan	Walworth	216.7	208.1	7.8	9.3	9.3	11.1	0.9	1.0
Devils	Sauk	5.7	5.1	3.5	3.7	33.9	39.2	3.9	5.7
Dowling	Douglas	6.6	6.6	3.7	3.7	45.8	45.8	2.8	2.8
Emily	Florence	7.2	8.2	3.9	25.2	16.2	23.8	0.5	1.5
Franklin	Oneida	2.6	2.6	4.3	4.7	17.4	13.9	1.6	1.5
Grindstone	Sawyer	2.6	4.6	2.8	6.5	21.6	32.5	2.3	5.3
Jag	Vilas	4.2	4.2	4.7	4.7	12.6	12.6	1.7	1.6
Joyce	Vilas	3.6	3.6	8.3	8.3	10.2	10.2	2.6	2.6
Little Arbor Vitae	Vilas	9.0	6.4	5.2	5.3	95.4	107.0	6.4	9.6
Little Green	Green Lake	29.0	1.7	5.3	8.0	23.7	26.9	1.9	2.8
Long	Oneida	3.0	3.1	5.5	5.7	8.1	7.1	1.5	1.7
Lost	Florence	3.5	5.0	11.3	8.6	10.6	8.5	1.4	2.5
Lower Bass	Langlade	4.0	4.7	6.1	6.7	9.5	9.9	1.8	1.8
Metonga	Forest	4.6	5.6	3.0	6.1	23.1	45.8	1.9	5.9
Monona	Dane	249.1	160.2	7.7	11.3	9.4	13.2	0.8	1.6
Noquebay	Marinette	22.9	17.1	6.2	0.5	76.8	16.1	2.8	0.3
North Two	Oneida	1.8	2.6	3.0	5.8	10.9	16.8	1.2	2.3
Pike	Washington	316.6	244.9	6.9	8.0	3.2	15.1	0.3	0.8
Pine	Waukesha	117.1	72.8	9.5	11.0	10.5	12.2	1.2	1.6
Rock	Jefferson	191.8	180.9	9.9	9.6	9.3	7.9	0.7	0.8
Round	Chippewa	5.0	5.0	4.7	4.7	14.0	14.0	1.6	1.6
Sand	Oneida	7.3	7.3	2.4	2.4	107.4	107.4	2.1	2.1
Sand	Polk	4.1	5.0	3.9	7.7	19.4	30.8	1.5	3.3
Sand	Sawyer	6.0	4.8	3.9	5.6	82.8	107.7	4.8	9.2
Scott	Barron	3.7	3.6	3.4	4.1	14.1	16.0	1.8	2.3
Shawano	Shawano	20.9	20.9	7.5	7.5	34.2	34.2	1.5	1.5
Shell	Washburn	2.9	3.7	1.1	2.0	22.4	29.0	1.3	2.0
Silver, Big	Waushara	16.4	12.5	9.3	15.2	13.9	20.3	1.7	1.6
Siskiwit	Bayfield	5.1	5.1	2.3	2.3	23.9	23.9	1.0	1.0
Sugar Camp	Oneida	1.6	2.1	1.6	4.3	13.0	15.9	1.3	2.2
Tahkodah	Bayfield	3.4	3.4	3.6	3.6	11.8	11.8	1.2	1.2
Twenty-Six	Burnett	5.3	5.1	10.8	12.0	39.6	96.6	2.7	6.3
Twin Bear	Bayfield	10.6	7.0	6.3	7.8	22.9	26.3	2.7	4.0
White Birch	Vilas	10.5	10.5	7.0	7.0	10.5	10.5	3.8	3.8
Wind	Racine	100.3	97.6	3.2	9.6	17.4	16.0	1.0	1.3

*D signifies deep hole values.

Hakanson's model was derived from lake data with relatively high sediment mercury levels.

Some adjustment of the constants in the model might produce a better fit for walleye in Wisconsin lakes, but the practicality of using this model is questionable. The time and financial investment involved in the collection and analysis of data for the required parameters may not be rewarded by a predictive capability better than that of a simpler lake water chemistry model. However, lake chemistry models assume that sediment mercury levels are not elevated from point source pollution, which is factored into the Hakanson model.

Water Chemistry Model

An all-subsets regression analysis (SAS procedure RSQUARE) was used to identify the best two- and three-variable models for predicting walleye mercury concentration for each lake from water chemistry parameters. Of all the water chemistry and morphometric parameters tested, the ionic character and degree of lake productivity appeared to be the most important predictors. The two best three-variable models from the mercury study lakes used either calcium, total phosphorus, and chlorophyll-*a* or alkalinity, total phosphorus, and chlorophyll-*a* as the independent variables (Table 20). The models were significant ($P < 0.001$) with R^2 values of 0.60 and 0.56, respectively. The best two-variable model used calcium and chlorophyll-*a* ($R^2 = 0.53$). Table 20 also shows the next best two-variable model and the best two-variable model not using chlorophyll-*a*, which used alkalinity and calcium ($R^2 = 0.42$). Because alkalinity and calcium were strongly correlated with one another, *t*-tests for individual parameters in this model were difficult to interpret. The *F*-test for both slope parameters differing from zero was highly significant.

Helwig and Heiskary (1985) performed a similar regression analysis on

TABLE 17. *Pearson correlation of sediment mercury on sediment sulfur of mercury study lakes.*

	All Lakes		pH < 7.0		pH ≥ 7.0	
	r	*P > F*	*r*	*P > F*	*r*	*P > F*
Tot. Hg on S	-0.19	0.24	-0.37	0.08	0.31	0.20
Tot. Hg(D)* on S(D)	-0.08	0.60	-0.51	0.01	0.39	0.09

*D signifies deep hole values.

TABLE 18. *Pearson correlation of sediment sulfur to sediment iron of mercury study lakes.*

	All Lakes		pH < 7.0		pH ≥ 7.0	
	r	*P > F*	*r*	*P > F*	*r*	*P > F*
S on Fe	-0.26	0.09	-0.27	0.21	-0.21	0.37
S(D)* on Fe(D)	-0.18	0.25	-0.34	0.12	-0.10	0.68

*D signifies deep hole values.

TABLE 19. *Test of Hakanson's (1980) model on 31 mercury study lakes.*

			(µg/g)				
Lake	BPI*	pH	Sed. Hg(A)**	Sed. Hg(D)[a]	Calc. Fish Hg[b]	Pred. Fish Hg(A)	Pred. Fish Hg(D)
Amnicon	4.2	6.8	0.20	0.20	0.89	0.56	0.56
Bass	3.1	5.7	0.14	0.20	1.34	0.74	0.93
Big Muskellunge	3.1	6.8	0.07	0.10	0.46	0.32	0.42
Butternut	3.1	7.3	0.07	0.10	0.20	0.28	0.37
Cedar	5.6	7.4	0.07	0.05	0.30	0.18	0.14
Clark	2.5	8.1	0.05	0.05	0.32	0.22	0.22
Delavan	7.2	8.1	0.05	0.05	0.03	0.11	0.11
Devils	3.5	6.8	0.20	0.20	0.92	0.64	0.64
Dowling	4.8	6.5	0.30	0.30	0.64	0.72	0.72
Emily	3.2	7.3	0.12	0.20	0.27	0.43	0.63
Grindstone	3.1	7.3	0.07	0.10	0.15	0.28	0.37
Jag	4.1	5.7	0.20	0.20	0.81	0.75	0.75
Little Arbor Vitae	5.1	6.8	0.10	0.05	0.13	0.29	0.16
Little Green	4.6	7.7	0.09	0.10	0.29	0.23	0.26
Long	3.5	5.0	0.14	0.05	0.54	0.78	0.33
Metonga	4.0	7.3	0.12	0.10	0.23	0.36	0.30
Monona	6.0	8.0	0.28	0.48	0.41	0.46	0.63
Noquebay	3.7	7.6	0.20	0.20	0.71	0.53	0.53
Pike	4.4	8.0	0.05	0.05	0.31	0.14	0.14
Rock	4.3	7.9	0.05	0.05	0.31	0.14	0.14
Round	4.5	6.0	0.20	0.20	0.61	0.64	0.64
Sand	4.6	6.3	0.30	0.30	0.69	0.79	0.79
Sand	4.7	7.1	0.08	0.10	0.28	0.26	0.29
Sand	4.4	6.8	0.20	0.20	0.55	0.54	0.54
Shawano	4.4	6.7	0.20	0.20	0.37	0.56	0.56
Shell	3.9	7.1	0.07	0.10	0.64	0.26	0.33
Silver, Big	3.4	7.9	0.20	0.20	0.63	0.61	0.61
Siskiwit	5.0	6.0	0.20	0.20	0.59	0.61	0.61
Tahkodah	3.7	6.0	0.10	0.10	1.82	0.43	0.43
Twin Bear	2.5	7.1	0.10	0.10	0.64	0.49	0.49
White Birch	4.1	6.6	0.10	0.10	0.59	0.35	0.35

*BPI is the bioproductivity index.
**A signifies area values.
[a]D signifies deep hole values.
[b]Mercury concentration for an 18-inch walleye calculated from regression model of mercury on fish length.

their dataset for lakes in northeastern Minnesota. Aluminum, pH, and TSIP (a measure of trophic status) were selected as the most important variables. Almost all of their lakes had alkalinities <400 µeq/L, which may have prevented the strong relationship with alkalinity that was found in our mercury study lakes.

TEST OF PREDICTIVE MODELS

The two-variable models were then tested on an independent dataset from 28 other lakes throughout Wisconsin for which enough walleye mercury data were available to evaluate mercury levels for 17-inch fish. The three-variable models could not be tested because total phosphorus data were not obtained for all lakes in the state dataset. The water chemistry data from these 28 lakes are presented in Table 21. Table 22 shows the lake fish mercury values calculated from the regression for each lake's walleyes and for those predicted from the water chemistry models. The models containing chlorophyll-*a* had correlation coefficients lower than those generated from the mercury study lakes (Table 23). The variation in sampling times and procedures among these source datasets may have introduced enough variability to influence the outcome of the model. Calcium and alkalinity are more conservative parameters and probably were not as affected by differences in time of sampling or analytical procedures, as indicated by the similar correlation coefficients for the two datasets. For the two-variable alkalinity and calcium model, which showed the best fit on the independent state dataset, 18 of the predicted values were greater than the calculated values, but in no case did the predicted concentration exceed 0.5 µg/g when the actual concentration was lower.

The practical use of these models is uncertain. The problem with the chlorophyll-*a* values may be due to differences in the analytical methods used in the data sources or an inherently poor predictive capability of chlorophyll-*a*. Both the individual linear regressions and the multiple regression using the mercury study lakes indicated a relationship between fish mercury and chlorophyll-*a* concentrations. To determine the source of the problem, the model should be tested on an additional independent dataset using carefully collected and analyzed chlorophyll-*a* samples.

An alternative would be to use the alkalinity-calcium two-variable model. Although this model did not fit as well as others on the mercury study dataset, it was the best of those tested on the state dataset. Because it is easier to characterize the ionic content than the productivity of a lake, this model may be the most useful.

Because many of the predicted values were higher than the calculated values, the model may require further adjustment. However, this procedure would entail an additional test on an independent dataset. An alternative to this test would be to use the results of the ANOVAs reported earlier to indicate those lakes that might contain fish with high concentrations of mercury.

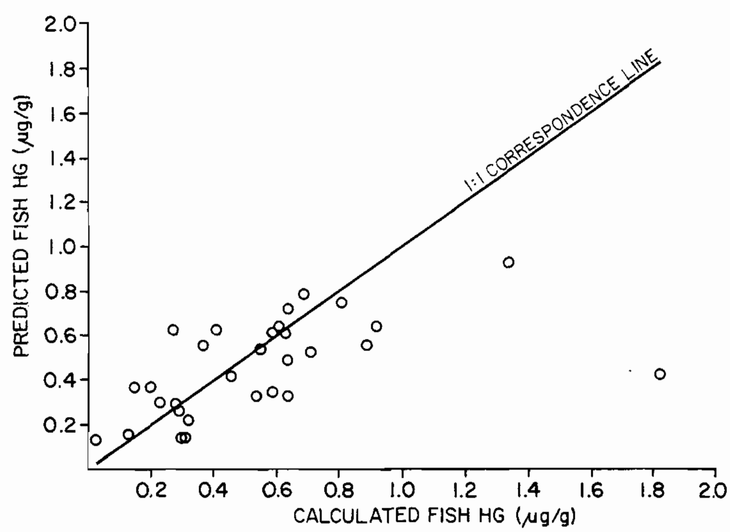


FIGURE 4. Test of Hakanson model on walleye mercury concentrations calculated from actual fish data.

TEST OF WATER CHEMISTRY RELATIONSHIPS

Fish mercury concentrations, pH, alkalinity, calcium, and chlorophyll-*a* values were available for 80 lakes throughout the state (Table 21 and Append. Table 4). These lakes included the 28 used to test the mercury lake model and an additional 52 lakes that lacked the necessary data to calculate a mercury concentration for the 17-inch walleye needed in the model. The data were assigned to the same length class and water chemistry categories as those from the mercury study lakes, and similar analyses were run.

The results are presented in Tables 24-27 and are similar to those from the mercury study lakes. Increased mean mercury concentrations were associated with increased fish length and decreased ionic content of the water. Between the two datasets there were two notable differences: (1) the lack of significant differences in the state dataset between mean mercury values for chlorophyll-*a* categories (Table 27), and (2) the considerably lower mean mercury concentrations in walleyes $\geqslant$20.0 inches for the ionic condition categories in the state dataset (Tables 24-26). The length distribution of the walleyes tested within the largest length class was similar for the two datasets. The lower mean mercury concentrations in larger fish may be the result of collection dates. The fish from the state dataset were collected between 1979 and 1986, with most collected between 1982 and 1985. The fish for the mercury study were collected in 1985 and 1986. The mercury analysis procedure may be more accurate than in the past. In any case, the mean mercury values for fish $\geqslant$20.0 inches from low pH lakes are well above the 0.5 µg/g Wisconsin standard, even if they are lower than those from the mercury study lakes.

From the state dataset we can characterize lakes that contained 17-inch walleyes with mean mercury concentrations above 0.5 µg/g. These lakes had pH <7.0, alkalinities <200 µeq/L, calcium concentrations <10 mg/L, and chlorophyll-*a* concentrations <5.0 µg/L. (Table 27 shows that none of the 15.0-19.9 inch fish from the state dataset exceeded the Wisconsin standard in any of the chlorophyll-*a* categories.) Only the alkalinity cut-off differed from that of the mercury study lakes, where it was <1,000 µeq/L. However, when the actual mean mercury concentrations are examined, the differences are not great. The mean concentration for the mercury study lakes was 0.51 µg/g compared to 0.46 µg/g for the state dataset. This difference could be due to sample size differences or lab analytical variability and indicates that values close to the category limits should be interpreted cautiously.

Information on walleye mercury concentrations from the mercury study lakes (38 lakes) and the state dataset lakes (80 lakes) can be combined and analyzed as in Tables 7-8 and 24-25. For the combined datasets we computed for each of the three length classes in the corresponding pH and alkalinity categories: (1) the lake mean walleye mercury concentration and (2) the 95% confidence interval about the mean. The results demonstrate that walleye mercury concentrations increase as fish size increases and as pH and alkalinity decrease (Fig. 5). The data also show that some hard-water lakes will have large walleyes ($\geqslant$20 inches) with mercury concentrations greater than the Wisconsin health standard. As more fish are tested, this analysis could be performed on smaller size ranges of fish and on narrower ranges of the water chemistry categories, which should decrease the size of the confidence intervals depicted in Figure 5.

By comparing our study results to those of Helwig and Heiskary (1985), we see that problem lakes in Wisconsin and Minnesota share the same characteristics. Decreasing ionic content of the water consistently shows a relationship with increasing fish mercury concentrations (Scheider et al. 1979; Akielaszek and Haines 1981; Wiener 1983, 1986; Rodgers and Beamish 1983; Verta et al. 1986). Characterization of these lake types allows the identification of specific lakes that are likely to contain contaminated walleyes and indicates potentially useful areas of research to understand the cycling of mercury in lakes.

TABLE 20. *Models derived from water chemistry data of mercury study lakes for predicting log-transformed fish mercury concentrations.*

Model	Parameter*	Coefficient	P**	R^2	$P > F$[a]
1	Intercept	-0.027	—	0.60	0.0001
	log Ca	-0.301	<0.001		
	Tot. P	2.905	0.037		
	Chl-*a*	-0.016	0.001		
2	Intercept	0.250	—	0.56	0.0001
	log alk.	-0.205	0.002		
	Tot. P	2.816	0.051		
	Chl-*a*	-0.016	0.001		
3	Intercept	-0.027	—	0.53	0.0001
	log Ca	-0.291	0.001		
	Chl-*a*	-0.009	0.007		
4	Intercept	0.244	—	0.54	0.0001
	log alk.	-0.199	0.004		
	Chl-*a*	-0.009	0.007		
5	Intercept	-0.662	—	0.42	0.0004
	log alk.	0.423	0.281		
	log Ca	-0.940	0.080		

*Units: $\log_{10}$ µg Hg/g wet weight of fish, Ca (mg/L), Tot. P (mg/L), alkalinity (µeq/L), chorophyll-*a* (µg/L).
***t*-test for the null hypothesis: parameter = 0, when the other parameters are included in the model.
[a]*F*-test for the null hypothesis: all slope parameters = 0.

TABLE 21. *Lake chemistry parameters for state dataset lakes.*

Lake	County	pH	Alk. (µeq/L)	Ca (mg/L)	Chl-*a* (µg/L)	Lake	County	pH	Alk. (µeq/L)	Ca (mg/L)	Chl-*a* (µg/L)
Amacoy	Rusk	7.2	760	10	36.1	Mid Eau Claire	Bayfield	7.6	1,280	19	5.6
Arrowhead*	Vilas	7.2	460	9	12.7	Moose	Sawyer	7.1	480	8	20.1
Ashegon	Sawyer	7.0	196	—	—	Musser*	Price	7.1	640	9	37.0
Balsam	Polk	7.7	1,380	19	18.4	Nagawicka	Waukesha	8.1	4,400	54	18.1
Bear*	Barron	7.5	1,520	18	19.7	Namekagon*	Bayfield	7.4	720	6	3.4
Bear	Ashland	7.2	796	—	—	Nebagamon	Douglas	7.4	599	10	0.0
Beauregard*	Douglas	6.1	47	3	6.8	Nelson	Sawyer	7.2	560	9	38.0
Big Arbor Vitae	Vilas	7.4	1,029	15	25.0	North Twin*	Vilas	7.5	821	10	5.1
Big Carr*	Oneida	6.4	25	1	0.7	Oswego	Vilas	6.3	47	10	3.5
Bird*	Oneida	6.4	54	1	1.1	Otter	Langlade	7.2	920	21	2.0
Brandy	Vilas	7.3	740	12	8.2	Owl*	Iron	7.4	100	1	10.4
Buffalo	Oneida	7.0	114	2	1.4	Pewaukee	Waukesha	8.1	3,800	41	12.3
Bullhead*	Manitowoc	7.8	2,620	28	185.0	Pine	Forest	7.5	740	10	10.8
Carrol*	Oneida	8.5	939	14	5.7	Pine	Lincoln	6.8	102	3	5.7
Clara	Lincoln	6.6	36	4	5.0	Potato*	Rusk	7.4	1,500	18	20.0
Clear	Oneida	7.2	140	2	0.6	Rib	Taylor	7.2	820	12	131.0
Cranberry	Price	6.9	300	1	85.5	Riley	Chippewa	6.4	80	2	13.3
Currie*	Oneida	5.7	30	1	3.6	Round	Burnett	7.4	1,560	19	67.5
Elk*	Price	7.1	640	9	12.3	Round	Sawyer	7.5	820	11	3.7
Escanaba	Vilas	7.1	300	5	4.6	Sand*	Florence	6.8	150	5	1.2
Franklin	Forest	7.1	260	5	1.6	Seven Island	Lincoln	6.8	262	9	3.2
Geneva*	Walworth	8.1	3,620	35	7.9	Seventeen	Oneida	6.3	27	1	1.5
Green, Big	Green Lake	8.1	3,500	32	32.0	Silver*	Lincoln	6.7	91	2	39.4
Hodstradt*	Oneida	6.3	33	1	1.3	Sissabagama	Sawyer	7.2	520	7	—
Kangaroo	Door	8.2	3,380	27	—	South Twin	Vilas	7.7	789	11	3.0
Keyes	Florence	6.8	916	—	—	Solberg*	Price	6.8	220	4	9.4
Lac La Belle	Waukesha	8.2	3,900	44	7.4	Spectacle	Vilas	6.2	170	2	0.0
Long	Chippewa	7.5	920	15	5.0	Squaw	St. Croix	7.1	580	4	168.0
Long*	Price	7.1	580	8	9.0	Sunset	Vilas	6.3	26	1	2.1
Long	Washburn	7.7	1,820	24	3.7	Tainter	Dunn	8.1	1,260	19	22.0
Lower Clam	Sawyer	7.4	736	—	—	Tomahawk	Oneida	7.5	680	9	—
Lower Kaubashine	Oneida	7.9	729	10	3.9	Trout*	Vilas	7.2	792	11	0.0
Lt. St. Germain	Vilas	7.3	608	8	—	Upper Kaubashine	Oneida	8.4	765	11	4.4
Lucerne	Forest	7.4	652	20	4.9	Vieux Desert*	Vilas	7.3	734	10	13.5
Lyman*	Douglas	7.0	400	8	11.2	Waubesa	Dane	8.6	3,400	30	40.0
Mayflower*	Marathon	7.9	2,020	21	22.0	Wheeler*	Oconto	8.0	2,060	17	3.5
McGrath	Oneida	5.2	-5	1	1.4	White Potato*	Oconto	7.5	1,220	18	6.1
Mendota	Dane	8.5	3,400	30	20.0	Windigo*	Sawyer	6.4	60	1	2.5
Menominee	Dunn	8.2	1,640	23	11.0	Winnebago	Winnebago	8.1	2,940	33	—
Mid	Oneida	7.3	940	13	25.0	Yellow*	Burnett	7.6	1,580	20	47.4

*Lakes with enough walleyes sampled to calculate a 17-inch fish mercury level.

TABLE 22. *Calculated and model-predicted fish mercury values for state dataset.*

Lake	County	(µg/g) Calc. Fish Hg	Model 3	Model 4	Model 5
Arrowhead	Vilas	0.30	0.38	0.40	0.37
Bear	Barron	0.34	0.27	0.27	0.32
Beauregard	Douglas	0.27	0.59	0.71	0.40
Big Carr	Oneida	0.58	0.93	0.91	0.85
Bird	Oneida	0.50	0.92	0.78	1.18
Bullhead	Manitowoc	0.30	0.01	0.01	0.27
Carrol	Oneida	0.22	0.39	0.40	0.33
Currie	Oneida	0.73	0.87	0.83	0.92
Elk	Price	0.25	0.38	0.38	0.42
Geneva	Walworth	0.38	0.28	0.29	0.25
Hodstradt	Oneida	0.67	0.91	0.85	0.96
Long	Price	0.39	0.43	0.41	0.46
Lyman	Douglas	0.99	0.41	0.42	0.39
Mayflower	Marathon	0.26	0.25	0.24	0.31
Musser	Price	0.53	0.23	0.23	0.42
Namekagon	Bayfield	0.53	0.52	0.44	0.65
North Twin	Vilas	0.34	0.43	0.42	0.43
Owl	Iron	1.19	0.76	0.57	1.53
Potato	Rusk	0.18	0.27	0.27	0.32
Sand	Florence	0.94	0.57	0.63	0.40
Silver	Lincoln	0.54	0.32	0.32	0.64
Solberg	Price	0.79	0.52	0.49	0.58
Trout	Vilas	0.38	0.48	0.47	0.38
Vieux Desert	Vilas	0.18	0.36	0.36	0.41
Wheeler	Oconto	0.25	0.38	0.36	0.38
White Potato	Oconto	0.36	0.36	0.38	0.29
Windigo	Sawyer	0.80	0.89	0.74	1.23
Yellow	Burnett	0.37	0.15	0.15	0.29

TABLE 23. *Pearson correlation of calculated to model-predicted values for log-transformed fish mercury.*

Model	Mercury Study r	State Dataset r
3	0.73	0.39
4	0.71	0.35
5	0.65	0.65

TABLE 24. *Mean walleye mercury values for length classes and lake pH categories using the state dataset.*

pH	All Lengths Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	<15.0 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.	15.0-19.9 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.	≥20.0 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<6.0	0.56	(0.25, 2)	A	0.51	(0.17, 2)	A	0.63	(0.00, 1)	A	1.07	(0.37, 1)	A
6.0-6.9	0.63	(0.39,18)	A	0.37	(0.15, 7)	A	0.58	(0.26,14)	A	1.04	(0.00,10)	A
7.0-7.9	0.40	(0.22,46)	AB	0.30	(0.16,20)	AB	0.39	(0.26,31)	A	0.60	(0.38,27)	A
≥8.0	0.29	(0.20,14)	B	0.14	(0.06, 5)	B	0.32	(0.16, 9)	A	0.39	(0.24, 7)	A

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparison of means carried out within length columns, not across rows.

TABLE 25. *Mean walleye mercury values for length classes and lake alkalinity categories using the state dataset.*

Alkalinity (µeq/L)	All Lengths Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	<15.0 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.	15.0-19.9 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.	≥20.0 Inches Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<200	0.69	(0.38,18)	A	0.39	(0.16,10)	A	0.64	(0.32,14)	A	1.03	(0.42,12)	A
200-999	0.42	(0.21,35)	B	0.31	(0.17,15)	A	0.39	(0.21,26)	B	0.65	(0.37,19)	B
≥1,000	0.29	(0.18,21)	C	0.18	(0.08, 9)	B	0.30	(0.14,15)	B	0.41	(0.22,14)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

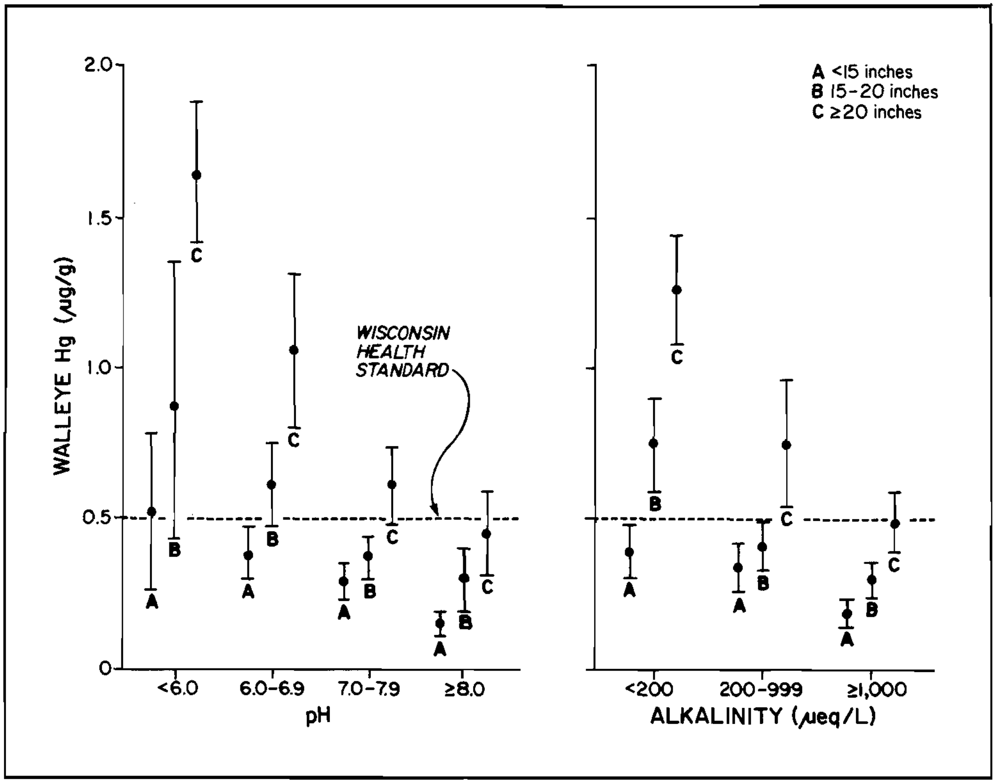


FIGURE 5. Walleye mercury concentration means and 95% confidence intervals for fish length classes in lakes of different pH and alkalinity categories. (Data combined from mercury study and state datasets. Means are based on individual lake mean concentrations of walleyes.)

TABLE 26. *Mean walleye mercury values for length classes and lake calcium categories using the state dataset.*

	All Lengths			< 15.0 Inches			15.0-19.9 Inches			≥20.0 Inches		
Calcium (mg/L)	Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<5	0.59	(0.25,20)	A	0.40	(0.15,11)	A	0.63	(0.31,14)	A	0.91	(0.37,12)	A
5-9	0.47	(0.29,15)	AB	0.32	(0.20, 8)	AB	0.51	(0.26,11)	A	0.72	(0.47, 8)	AB
≥10	0.37	(0.30,41)	B	0.19	(0.08,13)	B	0.29	(0.13,26)	B	0.54	(0.38,24)	B

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

TABLE 27. *Mean walleye mercury values for length classes and lake chlorophyll-a* categories using the state dataset.

	All Lengths			< 15.0 Inches			15.0-19.9 Inches			≥20.0 Inches		
Chl-*a* (mg/L)	Mean Hg (µg/g)	(SD,n)*	Sig. Comp.**	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.	Mean Hg (µg/g)	(SD,n)	Sig. Comp.
<5.0	0.56	(0.35,27)	A	0.32	(0.18,10)	A	0.47	(0.25,20)	A	0.83	(0.42,16)	A
5.0-9.9	0.43	(0.21,13)	A	0.30	(0.14, 4)	A	0.41	(0.21,11)	A	0.56	(0.32,18)	A
≥10.0	0.40	(0.26,31)	A	0.30	(0.17,16)	A	0.41	(0.31,18)	A	0.63	(0.44,18)	A

*n refers to number of lakes having mean walleye mercury concentrations used to calculate mean concentrations in the table.
**Significance of Bonferroni comparisons. Mean Hg levels with different designated letters are significantly different at $\alpha = 0.05$. Comparisons of means carried out within length columns, not across rows.

SUMMARY

Forty-three lakes were sampled four times from the summer of 1985 through the following winter to determine characteristic lake values for water chemistry parameters. The lake sediments also were sampled during the summer of 1985 to provide additional information about each lake. Mercury analyses were run on 231 walleyes that had been collected from 38 of the study lakes. Thirty-one lakes had enough walleyes collected to predict the mercury concentration of a standardized 17-inch fish. This length was similar to the median length of walleyes collected for our study and represented the average length of walleyes caught by anglers fishing Wisconsin lakes.

We found a positive correlation between fish length and mercury concentration for walleyes from all the lakes. Regression analyses identified two parameters that related closely to walleye mercury concentration: reduced levels of both (1) lake ionic character (pH, alkalinity, calcium concentration, and conductivity) and (2) productivity (chlorophyll-*a*). The lakes were next assigned to appropriate categories of these water chemistry parameters. The categories were defined by ranges of lake pH (<6.0, 6.0-6.9, 7.0-7.9, and ≥8.0); alkalinity (<200, 200-999, and ≥1,000 μeq/L); calcium (<5, 5-9, and ≥10 mg/L); conductivity (<50, 50-149, and ≥150 μmhos/cm); and chlorophyll-*a* (<5, 5-9, and ≥10 μg/L). Mean walleye mercury concentrations were compared between categories for statistically significant differences. Walleyes were then divided into three length classes (<15.0, 15.0-19.9, and ≥20.0 inches), and mean mercury concentrations between the same water chemistry categories were compared for each length class separately.

In all cases mean mercury concentrations for all length categories increased as lake pH, alkalinity, calcium, conductivity, and chlorophyll-*a* values decreased. Statistically significant differences between means were obtained for many of the comparisons. Within each parameter category, mercury concentrations increased as walleye length increased; larger fish were more contaminated. These same analyses also were performed on an independent dataset of 80 lakes where walleye mercury concentration and water chemistry data were available. Similar findings were obtained for pH, alkalinity, and calcium. Fish data for the mercury study and state datasets were combined, and lake mean concentrations and their 95% confidence intervals were computed for each fish length class and pH and alkalinity category.

We identified lake parameter categories having mean mercury concentrations greater than the Wisconsin standard of 0.5 μg/g wet weight. (Even if mean concentrations were greater than the limit, individual fish or fish from individual lakes could be below the limit.) The mean mercury concentrations of all length classes of walleyes in lakes with pH values <6.0 exceeded the Wisconsin standard. In lakes with pH 6.0-6.9, mean mercury concentrations exceeded the Wisconsin standard for walleyes ≥15.0 inches. In lakes with pH ≥7.0, mean mercury concentrations for walleyes <20.0 inches were below the 0.5 μg/g limit. However, mean mercury concentrations of walleyes >20.0 inches exceeded the Wisconsin standard in lakes of all pH categories and exceeded the FDA standard (1.0 μg/g) in lakes with pH <7.0. The mean mercury concentration of walleyes ≥20.0 inches exceeded the 0.5 μg/g limit in the mercury study lakes, but was less than the limit in the state dataset lakes for lakes with pH ≥8. When the two datasets were combined, the mean was slightly less than the limit, but not significantly different from the limit. Apparently, the older, larger fish in the hard-water lakes also can accumulate enough mercury to warrant concern. Similar results were obtained for the other water chemistry parameters, though the actual mean mercury concentrations depended on the assigned cut-off points that defined the categories.

Sediment chemistry characteristics were less conclusive, but some interesting differences between lake types were found. Mercury concentrations in the sediments of the study lakes were generally ≤0.2 μg/g dry weight, except in one lake where the sediments were contaminated by industrial and sewage discharges. Mercury concentrations were significantly higher in the sediments of soft-water lakes with pH values <7.0 than in the sediments of hard-water lakes with pH values ≥7.0. Organic content of the sediments, as represented by both percent ignition loss and total nitrogen concentration, also was significantly higher in the lakes with pH values <7.0. The relationship between sediment organic content and mercury has been considered important in the scientific literature. However, the differences in the relationship between mercury and organic content that we found between the soft-water and hard-water lakes will require further study to determine how they affect differences in walleye mercury concentrations.

The Hakanson (1980) model, which predicts northern pike mercury levels from lake pH, sediment mercury, and lake productivity data, was tested in our study. After some adjustments the model was a statistically significant predictor of walleye mercury concentrations in Wisconsin lakes. However, the usefulness of this model is limited because of the time and cost of collecting the necessary data. Furthermore, the predictive capability of a simpler lake chemistry model developed from our data was as good as the Hakanson model.

Based on our lake dataset, the best three-variable models for predicting mercury concentration in 17-inch walleyes used: (1) calcium, total phosphorus, and chlorophyll-*a* and (2) alkalinity, total phosphorus, and chlorophyll-*a* as independent variables. The best two-variable models used: (1) calcium and chlorophyll-*a* and (2) alkalinity and chlorophyll-*a*. The best of the two-variable models not involving chlorophyll-*a* used calcium and alkalinity. The two-variable models were tested on an independent dataset of 28 Wisconsin lakes not included in the mercury study dataset. Correlation coefficients of calculated vs. model-predicted mercury concentrations for a 17-inch walleye were determined for the same models on the two different datasets. The model that produced the best results on the state dataset used calcium and alkalinity, perhaps because of problems in determining chlorophyll-*a* levels for the state dataset.

Clearly, soft-water, poorly buffered, low pH lakes had the highest concentrations of mercury in walleyes. Northern Wisconsin has numerous lakes of this type. Our analyses also suggest that if a lake were to have its pH lowered, mercury concentrations in walleyes might increase. The mechanisms responsible for this increase are not clear and need further study.

APPENDIX

APPENDIX TABLE 1. *Walleyes collected from mercury study lakes.*

Lake	County	Lake Number	Walleye Length (inches)	Walleye Weight (kg)	Walleye Hg (µg/g)
Amnicon	Douglas	9	12.8	0.20	0.34
Amnicon	Douglas	9	13.6	0.25	0.32
Amnicon	Douglas	9	14.7	0.28	0.64
Amnicon	Douglas	9	15.1	0.45	0.33
Amnicon	Douglas	9	15.1	0.40	0.45
Amnicon	Douglas	9	18.4	0.91	0.66
Amnicon	Douglas	9	19.0	0.28	0.40
Amnicon	Douglas	9	19.9	1.14	0.80
Amnicon	Douglas	9	25.6	—	2.78
Bass	Price	14	16.7	0.65	1.60
Bass	Price	14	13.4	0.35	0.65
Bass	Price	14	15.7	0.60	1.30
Bass	Price	14	17.1	0.85	1.10
Bass	Price	14	21.3	1.75	1.50
Big Muskellunge	Vilas	15	10.2	0.15	0.11
Big Muskellunge	Vilas	15	14.4	0.38	0.28
Big Muskellunge	Vilas	15	20.0	1.18	0.56
Butternut	Forest	27	22.9	2.13	0.34
Butternut	Forest	27	17.5	0.63	0.21
Butternut	Forest	27	18.0	1.02	0.25
Butternut	Forest	27	18.6	0.85	0.20
Butternut	Forest	27	19.4	0.95	0.14
Butternut	Forest	27	22.2	1.80	0.28
Butternut	Forest	27	23.4	1.90	0.34
Cedar	Polk	1	14.4	0.45	0.06
Cedar	Polk	1	14.4	0.45	0.05
Cedar	Polk	1	15.3	0.51	0.10
Cedar	Polk	1	15.7	0.62	0.15
Cedar	Polk	1	14.5	0.45	0.04
Cedar	Polk	1	14.3	0.40	0.05
Clark	Door	32	17.2	0.68	0.22
Clark	Door	32	14.0	0.31	0.15
Clark	Door	32	14.1	0.37	0.20
Clark	Door	32	14.9	0.40	0.21
Clark	Door	32	16.9	0.57	0.51
Clark	Door	32	19.3	0.99	0.37
Clark	Door	32	22.3	1.56	0.39
Crystal	Sheboygan	36	22.7	1.93	0.65
Crystal	Sheboygan	36	13.2	0.28	0.21
Delavan	Walworth	42	13.5	0.40	0.18
Delavan	Walworth	42	16.7	0.75	0.07
Delavan	Walworth	42	16.8	0.80	0.07
Devils	Sauk	37	15.0	0.50	0.28
Devils	Sauk	37	11.4	0.26	0.56
Devils	Sauk	37	13.5	0.31	1.00
Devils	Sauk	37	19.7	1.19	1.70
Devils	Sauk	37	20.0	1.04	0.50
Dowling	Douglas	10	12.1	0.35	0.28
Dowling	Douglas	10	13.7	0.45	0.41
Dowling	Douglas	10	14.1	0.45	0.34
Dowling	Douglas	10	16.3	0.75	0.46
Dowling	Douglas	10	16.4	0.70	0.53
Dowling	Douglas	10	19.1	0.97	0.99
Dowling	Douglas	10	20.6	1.31	0.58
Dowling	Douglas	10	20.7	1.31	0.92
Dowling	Douglas	10	16.9	0.60	0.85
Dowling	Douglas	10	16.7	0.65	0.74
Emily	Florence	29	19.4	1.25	0.41
Emily	Florence	29	20.6	1.22	0.31
Emily	Florence	29	22.6	1.28	0.56
Franklin	Oneida	20	24.0	2.15	2.50
Franklin	Oneida	20	20.0	2.15	1.20
Franklin	Oneida	20	23.2	2.15	1.30
Grindstone	Sawyer	7	18.1	1.00	0.14
Grindstone	Sawyer	7	15.2	0.50	0.21
Grindstone	Sawyer	7	16.9	0.76	0.16
Grindstone	Sawyer	7	16.8	0.70	0.20
Jag	Vilas	16	25.1	2.05	2.20
Jag	Vilas	16	23.0	1.90	1.50
Jag	Vilas	16	14.0	0.37	0.42
Jag	Vilas	16	19.3	1.17	0.77
Jag	Vilas	16	16.2	0.62	0.44
Jag	Vilas	16	20.7	1.30	1.20
Jag	Vilas	16	21.5	2.05	1.70
Jag	Vilas	16	23.0	1.90	1.50
Joyce	Vilas	17	20.9	1.45	1.80
Little Arbor Vitae	Vilas	18	17.2	0.82	0.12
Little Arbor Vitae	Vilas	18	17.9	0.75	0.11
Little Arbor Vitae	Vilas	18	17.4	0.69	0.10
Little Arbor Vitae	Vilas	18	23.1	1.67	0.29
Little Green	Green Lake	35	17.7	0.94	0.29
Little Green	Green Lake	35	18.9	1.14	0.40
Little Green	Green Lake	35	19.1	1.25	0.28
Little Green	Green Lake	35	19.3	1.25	0.28
Little Green	Green Lake	35	22.6	2.10	0.35
Long	Oneida	21	19.1	1.18	0.68
Long	Oneida	21	18.1	0.91	0.65
Long	Oneida	21	25.8	2.32	2.20
Metonga	Forest	28	21.0	1.41	0.25
Metonga	Forest	28	16.9	0.80	0.28
Metonga	Forest	28	18.9	0.89	0.14
Monona	Dane	39	14.0	0.37	0.11
Monona	Dane	39	24.3	1.93	1.10
Monona	Dane	39	21.8	1.64	0.27
Monona	Dane	39	22.3	1.76	0.81
Monona	Dane	39	28.0	3.01	0.26
Noquebay	Marinette	31	21.0	1.50	1.40
Noquebay	Marinette	31	13.4	0.32	0.33
Noquebay	Marinette	31	17.1	0.65	0.58
Noquebay	Marinette	31	17.0	0.75	0.24
Noquebay	Marinette	31	18.0	0.65	0.74
Noquebay	Marinette	31	21.0	1.45	0.76
Noquebay	Marinette	31	14.8	0.48	0.36
Noquebay	Marinette	31	16.0	0.68	0.61
Noquebay	Marinette	31	16.5	0.74	0.50
Noquebay	Marinette	31	17.3	0.71	0.57
Noquebay	Marinette	31	17.6	0.80	0.67
Noquebay	Marinette	31	17.8	0.85	0.67
Noquebay	Marinette	31	19.5	1.28	1.30
Noquebay	Marinette	31	20.7	1.68	1.30
Noquebay	Marinette	31	23.0	2.05	0.81
Noquebay	Marinette	31	23.4	2.10	1.00
North Two	Oneida	22	19.8	1.03	0.70
North Two	Oneida	22	19.9	1.17	0.67
Pike	Washington	38	14.6	0.43	0.11
Pike	Washington	38	15.1	0.50	0.13
Pike	Washington	38	15.3	0.50	0.14
Pike	Washington	38	16.3	0.65	0.15
Pike	Washington	38	20.0	1.50	0.37
Pike	Washington	38	20.7	1.34	0.40
Pike	Washington	38	20.8	1.51	0.40
Pike	Washington	38	22.8	1.90	0.84
Pike	Washington	38	23.7	2.05	0.80
Pike	Washington	38	18.7	1.00	0.52

APPENDIX TABLE 1. *Continued.*

Lake	County	Lake Number	Walleye Length (inches)	Walleye Weight (kg)	Walleye Hg (µg/g)
Rock	Jefferson	40	16.4	0.70	0.24
Rock	Jefferson	40	16.7	0.75	0.21
Rock	Jefferson	40	16.9	0.60	0.19
Rock	Jefferson	40	24.7	1.95	0.68
Rock	Jefferson	40	14.6	0.55	0.15
Rock	Jefferson	40	14.8	0.58	0.15
Rock	Jefferson	40	14.8	0.56	0.22
Round	Chippewa	3	13.5	0.40	0.17
Round	Chippewa	3	21.9	1.76	1.00
Round	Chippewa	3	18.5	0.86	0.90
Round	Chippewa	3	21.1	1.72	1.00
Round	Chippewa	3	13.5	0.40	0.21
Round	Chippewa	3	23.3	2.20	2.10
Round	Chippewa	3	25.0	3.00	1.00
Round	Chippewa	3	15.9	0.64	0.26
Round	Chippewa	3	16.3	0.71	0.31
Round	Chippewa	3	18.2	1.06	0.31
Round	Chippewa	3	22.6	1.97	1.10
Round	Chippewa	3	23.7	2.60	1.20
Round	Chippewa	3	14.9	0.50	0.30
Sand	Oneida	23	20.7	1.40	0.83
Sand	Oneida	23	21.6	1.55	0.93
Sand	Oneida	23	24.8	2.25	1.40
Sand	Oneida	23	13.9	0.40	0.47
Sand	Oneida	23	13.6	0.35	0.30
Sand	Oneida	23	16.4	0.54	0.49
Sand	Oneida	23	14.0	—	0.32
Sand	Oneida	23	14.6	—	0.75
Sand	Polk	2	16.7	0.65	0.32
Sand	Polk	2	16.7	0.65	0.24
Sand	Polk	2	17.0	0.68	0.37
Sand	Polk	2	17.2	0.80	0.22
Sand	Polk	2	17.6	0.71	0.21
Sand	Polk	2	17.8	0.77	0.32
Sand	Polk	2	13.5	0.57	0.26
Sand	Sawyer	8	16.0	0.55	0.27
Sand	Sawyer	8	13.4	0.34	0.28
Sand	Sawyer	8	15.0	0.54	0.34
Sand	Sawyer	8	15.0	0.47	0.32
Sand	Sawyer	8	15.3	0.55	0.43
Scott	Barron	4	21.5	1.65	0.91
Scott	Barron	4	24.5	2.53	0.98
Scott	Barron	4	19.0	1.14	1.10
Scott	Barron	4	20.8	1.65	0.86
Scott	Barron	4	21.3	1.56	0.88
Scott	Barron	4	23.0	2.22	0.80
Scott	Barron	4	19.6	1.19	0.96
Shawano	Shawano	33	19.2	0.80	0.43
Shawano	Shawano	33	19.3	1.00	0.29
Shawano	Shawano	33	20.2	1.10	0.39
Shawano	Shawano	33	16.7	0.60	0.30
Shawano	Shawano	33	16.8	0.65	0.53
Shawano	Shawano	33	17.1	0.60	0.30
Shawano	Shawano	33	17.7	0.75	0.39
Shawano	Shawano	33	16.2	0.70	0.32
Shawano	Shawano	33	22.2	2.33	0.40
Shawano	Shawano	33	22.4	2.07	0.43
Shawano	Shawano	33	22.4	2.10	0.45
Shawano	Shawano	33	22.0	1.80	0.80
Shell	Washburn	5	11.0	0.20	0.16
Shell	Washburn	5	12.5	0.25	0.22
Shell	Washburn	5	15.0	0.50	0.25
Shell	Washburn	5	16.0	0.60	0.43
Shell	Washburn	5	14.3	0.45	0.45
Shell	Washburn	5	18.0	0.75	0.60
Shell	Washburn	5	20.5	1.22	0.72
Shell	Washburn	5	20.5	1.42	0.93
Shell	Washburn	5	14.3	0.40	0.46
Shell	Washburn	5	16.9	0.80	0.83
Shell	Washburn	5	17.8	0.77	0.61
Shell	Washburn	5	18.2	0.77	0.57
Silver, Big	Waushara	34	15.4	0.57	0.23
Silver, Big	Waushara	34	16.5	0.68	0.31
Silver, Big	Waushara	34	22.3	1.93	1.20
Silver, Big	Waushara	34	14.3	0.48	0.24
Silver, Big	Waushara	34	14.4	0.51	0.30
Siskiwit	Bayfield	11	12.4	0.30	0.17
Siskiwit	Bayfield	11	13.7	0.35	0.47
Siskiwit	Bayfield	11	14.2	0.40	0.40
Siskiwit	Bayfield	11	14.9	0.40	0.46
Siskiwit	Bayfield	11	16.0	0.50	0.60
Siskiwit	Bayfield	11	17.0	0.70	0.40
Siskiwit	Bayfield	11	25.5	2.90	1.40
Siskiwit	Bayfield	11	18.5	0.80	0.82
Siskiwit	Bayfield	11	15.8	0.60	0.78
Sugar Camp	Oneida	24	21.1	1.62	2.20
Sugar Camp	Oneida	24	20.3	1.25	0.98
Sugar Camp	Oneida	24	18.8	1.05	1.20
Sugar Camp	Oneida	24	19.2	1.16	1.20
Sugar Camp	Oneida	24	20.4	—	1.60
Sugar Camp	Oneida	24	21.1	1.62	2.40
Sugar Camp	Oneida	24	20.3	1.25	0.95
Tahkodah	Bayfield	12	17.9	0.65	1.80
Tahkodah	Bayfield	12	21.2	1.28	1.90
Tahkodah	Bayfield	12	21.9	1.36	1.70
Twin Bear	Bayfield	13	16.2	0.70	0.27
Twin Bear	Bayfield	13	15.5	0.50	0.22
Twin Bear	Bayfield	13	19.0	0.90	0.84
White Birch	Vilas	19	21.2	1.53	1.30
White Birch	Vilas	19	24.3	2.50	1.00
White Birch	Vilas	19	14.7	0.51	0.38
White Birch	Vilas	19	15.7	0.57	0.35
White Birch	Vilas	19	16.0	0.57	0.41
White Birch	Vilas	19	17.7	0.88	0.44
White Birch	Vilas	19	19.5	1.36	0.50
Wind	Racine	43	19.5	1.20	0.80
Wind	Racine	43	19.1	1.10	0.17

APPENDIX TABLE 2. *Water chemistry analyses of the mercury study lakes.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Amnicon (Douglas)	23 Jul 85	0.0	22.0	7.5	51	7.6	400(g)*	5	40	2.1	4	15
		4.6	22.0	7.4	52	7.5	—	—	—	—	—	—
		6.1	18.0	3.9	—	—	—	—	—	—	—	—
		7.6	17.5	0.0	—	—	—	—	—	—	—	—
		8.8	17.5	0.0	67	7.0	—	—	—	—	—	—
	20 Aug 85**	0.0	17.8	8.5	—	—	398(g)	5	—	3.5	6	16
		4.6	17.5	—	—	—	—	—	—	—	—	—
		8.5	17.5	7.6	—	—	—	—	—	—	—	—
	22 Oct 85	0.0	9.5	10.0	52	7.3	364(g)	5	30	2.7	5	17
		7.9	9.5	11.0	55	7.3	—	—	—	—	—	—
	11 Feb 86	0.9	1.0	12.6	—	7.1	432(g)	7	40	2.7	—	20
		4.6	4.5	2.7	—	6.9	—	—	—	—	—	—
		7.9	5.0	2.0	—	6.8	—	—	—	—	—	—
Bass (Price)	24 Jul 85	0.0	21.5	7.0	23	6.6	59(g)	2	30	3.4	2	7
		6.1	12.0	1.6	27	5.8	—	—	—	—	—	—
		11.6	7.0	1.4	32	5.9	—	—	—	—	—	—
	19 Aug 85**	0.0	18.5	7.7	—	—	53(g)	2	—	4.2	4	9
		6.5	11.0	0.1	—	—	—	—	—	—	—	—
		11.2	7.0	0.0	—	—	—	—	—	—	—	—
	30 Oct 85	0.0	9.0	9.6	27	6.0	47(g)	2	40	3.0	—	11
		13.1	9.0	9.6	31	6.2	—	—	—	—	—	—
	12 Feb 86	0.9	0.5	10.8	28	6.1	51(g)	2	40	2.1	—	9
		6.1	3.1	6.7	32	6.0	—	—	—	—	—	—
		11.9	3.8	3.9	35	5.9	—	—	—	—	—	—
Big Muskellunge (Vilas)	10 Jul 85	0.0	21.0	8.5	46	7.8	320	5	5	5.2	2	7
		6.1	19.0	8.9	—	—	—	—	—	—	—	
		9.1	16.8	8.1	49	7.4	—	—	—	—	—	—
		15.2	9.3	3.1	—	—	—	—	—	—	—	—
		18.3	8.8	0.1	—	—	—	—	—	—	—	—
		20.4	8.7	0.1	57	6.6	—	—	—	—	—	—
	6 Aug 85**	0.0	22.2	8.5	—	7.4	360(g)	5	—	6.6	2	10
		10.0	16.2	5.5	—	6.6	—	—	—	—	—	—
		13.2	9.4	0.8	—	6.2	—	—	—	—	—	—
		19.0	8.2	0.0	—	6.2	—	—	—	—	—	—
	15 Oct 85	0.0	10.0	8.9	45	6.8	370(g)	5	5	5.2	3	11
		20.1	10.0	8.5	45	7.0	—	—	—	—	—	—
	4 Feb 86	0.9	0.8	11.6	53	6.6	371(g)	6	5	10.7	—	10
		10.7	3.0	7.4	57	6.6	—	—	—	—	—	—
		19.8	4.3	3.0	60	6.6	—	—	—	—	—	—
Butternut (Forest)	10 Jul 85**	0.0	20.3	8.8	—	7.2	759(g)	9	—	6.6	3	7
		8.5	18.5	7.0	—	6.5	—	—	—	—	—	—
		12.5	16.7	2.8	—	6.2	—	—	—	—	—	—
	6 Aug 85	0.0	22.5	7.9	74	8.1	780	9	5	4.9	2	10
		6.1	22.0	7.9	86	8.1	—	—	—	—	—	—
		9.1	21.0	5.6	—	—	—	—	—	—	—	—
		11.9	18.0	0.9	135	7.3	—	—	—	—	—	—
	29 Oct 85	0.0	10.0	10.4	104	7.2	660	9	5	4.6	4	13
		12.2	10.0	10.5	112	7.4	—	—	—	—	—	—
	3 Feb 86	0.9	0.8	13.1	82	7.6	800	10	5	5.8	—	10
		7.6	2.4	10.2	87	7.5	—	—	—	—	—	—
		13.1	5.5	4.6	146	7.3	—	—	—	—	—	—
Cedar (Polk)	22 Jul 85**	0.0	24.7	9.6	—	8.3	2,008	25	—	2.6	19	52
		5.0	23.3	8.8	—	8.2	—	—	—	—	—	—
		5.5	23.2	—	—	7.9	—	—	—	—	—	—
		7.0	21.7	6.2	—	—	—	—	—	—	—	—
		8.0	21.5	1.0	—	—	—	—	—	—	—	—
		8.5	21.4	0.0	—	6.7	—	—	—	—	—	—
	26 Aug 85	0.0	21.5	9.7	204	9.1	2,100	26	15	1.5	58	133
		4.6	20.0	8.5	209	9.0	—	—	—	—	—	—
		7.6	20.0	7.9	215	9.0	—	—	—	—	—	—
	21 Oct 85	0.0	10.5	11.6	198	9.1	2,000	28	15	2.1	20	46
		7.5	10.0	10.9	207	9.0	—	—	—	—	—	—
	10 Feb 86	0.9	1.0	7.4	263	7.1	2,400	34	10	4.3	—	31
		4.6	3.7	6.6	257	7.2	—	—	—	—	—	—
		7.0	5.0	4.3	271	7.2	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Clark (Door)	15 Jul 85	0.0	25.0	8.0	352	8.4	3,460	37	15	1.4	2	5
		3.0	24.5	8.1	355	8.4	—	—	—	—	—	—
		6.1	23.0	7.7	363	8.4	—	—	—	—	—	—
	14 Aug 85**	0.0	22.0	8.1	—	8.7	3,646	33	—	2.6	2	6
		3.0	22.0	8.1	—	8.7	—	—	—	—	—	—
		6.8	21.8	7.9	—	8.6	—	—	—	—	—	—
	3 Oct 85	0.0	11.5	10.1	360	8.5	3,540	36	15	3.0	2	7
		6.4	11.5	10.0	374	8.4	—	—	—	—	—	—
	9 Jan 86	0.9	1.0	11.7	442	7.7	4,600	56	20	3.2	—	5
		6.4	3.8	7.2	561	7.6	—	—	—	—	—	—
Clear (Langlade)	5 Aug 85**	0.0	24.0	7.1	17	5.1	0(g)	<1	15	4.0	4	11
		3.0	23.0	7.1	19	5.1	—	—	—	—	—	—
		4.6	19.5	4.7	—	—	—	—	—	—	—	—
		6.1	13.5	0.2	24	5.1	—	—	—	—	—	—
	28 Aug 85	0.0	20.0	8.3	19	5.1	-10(g)	<1	15	3.8	4	12
		3.0	18.8	7.8	20	5.0	—	—	—	—	—	—
		6.1	15.5	3.6	24	5.0	—	—	—	—	—	—
	14 Oct 85	0.0	11.5	9.5	20	4.7	-13(g)	<1	20	2.7	6	13
		6.4	10.5	8.7	24	4.8	—	—	—	—	—	—
	22 Jan 86	0.9	1.0	12.1	18	5.0	4	1	30	1.8	—	9
		5.8	3.8	8.6	20	5.1	—	—	—	—	—	—
Crystal (Sheboygan)	15 Jul 85	0.0	24.5	8.4	341	8.6	2,780	28	5	3.7	3	6
		7.6	17.5	7.1	—	—	—	—	—	—	—	—
		9.1	12.5	1.0	367	7.7	—	—	—	—	—	—
		12.2	9.3	0.1	—	—	—	—	—	—	—	—
		18.3	7.5	0.1	369	7.3	—	—	—	—	—	—
	14 Aug 85**	0.0	24.0	8.1	—	8.7	2,980	26	—	4.5	1	9
		9.0	12.0	0.6	—	7.7	—	—	—	—	—	—
		17.5	6.0	0.0	—	6.9	—	—	—	—	—	—
	17 Oct 85	0.0	13.0	9.5	334	8.5	2,960	31	5	3.4	7	18
		12.2	12.5	8.9	—	—	—	—	—	—	—	—
		13.7	8.5	0.9	385	7.6	—	—	—	—	—	—
		18.6	7.5	0.0	447	7.1	—	—	—	—	—	—
	31 Jan 86	0.9	0.8	11.7	406	8.0	3,260	34	5	7.3	—	12
		9.1	2.8	7.7	402	8.0	—	—	—	—	—	—
		18.0	3.3	3.6	377	7.8	—	—	—	—	—	—
Delavan (Walworth)	2 Jul 85**	0.0	23.3	13.9	—	9.0	3,162	32	—	1.4	74	105
		4.5	22.0	10.5	—	9.0	—	—	—	—	—	—
		8.0	19.8	4.0	—	—	—	—	—	—	—	—
		15.8	18.7	0.0	—	7.8	—	—	—	—	—	—
	30 Jul 85	0.0	24.0	6.6	—	8.4	3,034	30	—	1.0	44	103
		10.0	22.2	1.3	—	7.7	—	—	—	—	—	—
		11.0	21.0	0.9	—	—	—	—	—	—	—	—
		15.3	18.3	0.0	—	7.0	—	—	—	—	—	—
	25 Nov 85	0.0	4.5	11.3	509	8.0	3,400	42	15	2.1	19	109
		16.2	4.5	11.2	501	8.1	—	—	—	—	—	—
	30 Jan 86	0.9	1.5	11.1	802	8.0	3,700	43	10	10.4	—	102
		4.1	2.0	10.1	785	8.1	—	—	—	—	—	—
		15.8	3.5	6.9	560	8.0	—	—	—	—	—	—
Devils (Sauk)	24 Jun 85[a]	1.5	—	9.7	—	—	—	—	—	5.6	2	13
	26 Jul 85**	0.0	23.6	8.0	—	7.9	448(g)	7	—	8.5	4	10
		9.0	17.5	6.2	—	6.2	—	—	—	—	—	—
		11.0	11.0	3.2	—	—	—	—	—	—	—	—
		12.0	9.5	0.5	—	—	—	—	—	—	—	—
		13.5	8.2	0.0	—	6.0	—	—	—	—	—	—
	16 Oct 85	0.0	13.0	9.4	74	7.1	438(g)	7	10	3.2	7	23
		13.1	13.0	8.6	77	7.2	—	—	—	—	—	—
	29 Jan 86	0.9	0.5	15.7	77	7.0	460	8	5	8.5	—	9
		7.6	1.9	11.6	78	7.0	—	—	—	—	—	—
		14.0	4.0	6.8	95	7.0	—	—	—	—	—	—
Dowling (Douglas)	23 Jul 85	0.0	22.0	6.4	46	7.2	290(g)	5	100	1.4	3	28
		3.0	22.0	6.1	49	7.2	—	—	—	—	—	—
	20 Aug 85**	0.0	17.5	7.8	—	—	408(g)	6	—	1.7	12	48
		3.7	17.0	7.0	—	—	—	—	—	—	—	—
	22 Oct 85	0.0	9.5	9.4	42	7.2	289(g)	4	75	1.5	5	37
		3.4	9.5	9.3	43	7.2	—	—	—	—	—	—
	11 Feb 86	0.0	1.5	5.7	39	6.7	371(g)	6	80	1.5	—	14
		3.0	4.7	2.5	38	6.7	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Emily	9 Jul 85**	0.0	23.0	8.1	—	8.0	1,506	19	—	3.1	3	8
(Florence)		6.0	18.0	4.1	—	7.2	—	—	—	—	—	—
		9.0	10.0	0.0	—	—	—	—	—	—	—	—
		12.0	8.5	0.0	—	6.8	—	—	—	—	—	—
	6 Aug 85	0.0	23.5	7.0	187	8.8	1,540	20	10	3.1	3	10
		6.1	19.0	5.0	185	8.3	—	—	—	—	—	—
		7.6	14.5	0.2	—	—	—	—	—	—	—	—
		12.2	9.5	0.0	221	7.5	—	—	—	—	—	—
	29 Oct 85	0.0	10.0	10.5	188	7.9	1,480	20	5	4.0	4	10
		12.5	10.0	10.3	192	7.9	—	—	—	—	—	—
	3 Feb 86	0.9	1.0	4.6	530	7.1	1,760	22	10	3.0	—	9
		6.1	4.4	2.4	494	7.1	—	—	—	—	—	—
		11.9	4.9	1.6	488	7.1	—	—	—	—	—	—
Franklin	9 Jul 85	0.0	25.5	7.9	19	5.6	160	1	5	5.9	2	6
(Oneida)		3.0	24.5	7.9	19	5.8	—	—	—	—	—	—
		6.1	23.5	6.4	21	5.8	—	—	—	—	—	—
	5 Aug 85**	0.0	23.3	7.8	—	5.1	8(g)	2	—	6.3	2	9
		3.5	23.2	8.1	—	5.1	—	—	—	—	—	—
		6.0	23.2	8.1	—	4.7	—	—	—	—	—	—
	30 Oct 85	0.0	8.5	10.3	17	5.7	6(g)	2	5	5.2	5	12
		7.3	8.5	10.6	19	5.7	—	—	—	—	—	—
	24 Jan 86	0.9	0.9	14.2	20	6.7	20	2	5	4.9	—	9
		5.5	4.0	5.5	24	6.6	—	—	—	—	—	—
Grindstone	22 Jul 85	0.0	23.0	8.2	103	8.4	960	13	10	5.2	2	7
(Sawyer)		9.1	19.0	6.9	108	7.7	—	—	—	—	—	—
		12.0	15.5	2.1	—	—	—	—	—	—	—	—
		15.0	11.5	0.0	—	—	—	—	—	—	—	—
		17.8	11.0	0.0	122	7.1	—	—	—	—	—	—
	21 Aug 85**	0.0	18.5	8.3	—	—	1,058	13	—	4.2	5	10
		12.0	16.0	5.1	—	—	—	—	—	—	—	—
		13.5	13.0	0.7	—	—	—	—	—	—	—	—
		16.1	10.5	0.0	—	—	—	—	—	—	—	—
	21 Oct 85	0.0	10.5	11.1	104	8.2	900	13	10	2.7	8	19
		9.1	10.5	—	110	8.0	—	—	—	—	—	—
		17.4	10.5	9.4	107	7.7	—	—	—	—	—	—
	13 Feb 86	0.9	0.5	12.3	109	6.9	1,000	13	5	9.8	—	9
		7.6	1.9	10.4	112	7.0	—	—	—	—	—	—
		14.6	3.3	4.9	132	7.0	—	—	—	—	—	—
Jag	9 Jul 85**	0.0	23.7	8.2	21	5.6	42(g)	2	10	3.1	3	17
(Vilas)		3.5	23.0	7.8	22	5.6	—	—	—	—	—	—
	7 Aug 85	0.0	22.5	6.9	20	6.1	44(g)	2	10	4.3	1	12
		3.7	22.5	7.0	21	6.2	—	—	—	—	—	—
	10 Oct 85	0.0	8.0	9.9	24	—	21(g)	2	10	4.3	2	9
		4.0	8.0	9.6	25	—	—	—	—	—	—	—
	23 Jan 86	0.9	0.9	12.9	22	5.6	40	2	10	4.0	—	9
		3.7	4.2	6.2	35	5.6	—	—	—	—	—	—
Joyce	10 Jul 85**	0.0	22.7	9.0	—	5.9	-3(g)	1	—	6.0	3	13
(Vilas)		6.0	16.3	10.8	—	6.0	—	—	—	—	—	—
		10.0	9.0	4.4	—	5.2	—	—	—	—	—	—
	7 Aug 85	0.0	22.5	7.5	19	5.9	6(g)	1	5	6.7	2	8
		6.1	20.0	8.9	21	5.6	—	—	—	—	—	—
		9.0	11.5	1.5	—	—	—	—	—	—	—	—
		12.2	10.0	1.7	28	5.6	—	—	—	—	—	—
	28 Oct 85	0.0	10.0	9.9	17	5.5	3(g)	1	5	4.9	2	8
		12.5	10.0	9.9	27	5.5	—	—	—	—	—	—
	23 Jan 86	0.9	0.9	12.6	20	5.2	20	1	5	7.6	—	10
		7.6	4.0	4.5	25	5.3	—	—	—	—	—	—
		12.5	4.3	4.9	28	5.3	—	—	—	—	—	—
Little Arbor Vitae	2 Jul 85	0.0	22.5	8.7	108	7.4	1,000	13	20	2.4	7	33
(Oneida)		4.6	19.5	6.9	115	7.4	—	—	—	—	—	—
		6.0	18.9	4.6	—	—	—	—	—	—	—	—
		7.9	18.5	6.8	124	7.3	—	—	—	—	—	—
	5 Aug 85**	0.0	23.0	10.5	—	8.6	1,098	14	—	0.9	78	75
		6.5	22.0	2.4	—	6.5	—	—	—	—	—	—
		8.0	20.5	0.3	—	6.4	—	—	—	—	—	—
	10 Oct 85	0.0	9.5	8.9	107	7.3	—	13	10	2.2	8	36
		8.5	9.0	9.1	108	7.3	—	—	—	—	—	—
	24 Jan 86	0.9	0.4	8.8	90	6.5	1,100	14	10	3.0	—	26
		4.6	3.5	3.5	126	6.6	—	—	—	—	—	—
		8.2	5.0	0.1	218	8.2	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Little Green (Green Lake)	18 Jul 85**	0.0	24.5	8.8	—	8.7	3,110	34	—	1.9	37	250
		5.5	22.3	7.1	—	8.5	—	—	—	—	—	—
		7.0	20.9	6.9	—	—	—	—	—	—	—	—
		7.5	20.7	0.0	—	7.0	—	—	—	—	—	—
	8 Aug 85	0.0	24.0	8.8	328	9.1	3,100	34	30	0.9	49	240
		3.7	23.5	6.2	336	8.9	—	—	—	—	—	—
		5.5	22.8	1.6	—	—	—	—	—	—	—	—
		7.0	22.5	0.4	360	8.4	—	—	—	—	—	—
	17 Oct 85	0.0	11.0	7.4	322	8.2	3,020	34	20	1.8	4	240
		7.6	11.0	6.9	325	8.4	—	—	—	—	—	—
	31 Jan 86	0.9	1.0	7.6	435	7.3	3,380	39	10	6.7	—	110
		3.0	2.8	4.0	447	7.3	—	—	—	—	—	—
		6.1	3.8	3.6	467	7.3	—	—	—	—	—	—
Long (Oneida)	9 Jul 85	0.0	25.0	8.2	13	5.2	120	<1	5	7.0	2	10
		4.6	22.5	8.4	16	5.3	—	—	—	—	—	—
		7.6	13.0	11.6	—	—	—	—	—	—	—	—
		9.1	10.5	6.0	21	5.2	—	—	—	—	—	—
	6 Aug 85**	0.0	23.3	8.0	—	4.4	8(g)	<1	—	8.5	3	7
		7.0	18.3	10.9	—	4.4	—	—	—	—	—	—
		9.0	10.7	11.9	—	4.9	—	—	—	—	—	—
		10.5	9.9	5.0	—	4.4	—	—	—	—	—	—
	29 Oct 85	0.0	10.0	10.0	16	5.2	5(g)	<1	5	6.4	2	7
		10.4	10.0	9.8	22	5.1	—	—	—	—	—	—
	4 Feb 86	0.9	1.5	13.2	18	5.3	4(g)	1	5	6.1	—	6
		6.1	4.0	5.1	19	5.1	—	—	—	—	—	—
		11.0	4.0	5.6	22	5.1	—	—	—	—	—	—
Lost (Florence)	9 Jul 85**	0.0	23.0	8.7	—	6.2	27(g)	1	—	5.1	2	7
		6.5	20.0	9.2	—	6.5	—	—	—	—	—	—
		13.0	10.0	5.4	—	5.2	—	—	—	—	—	—
	6 Aug 85	0.0	23.5	7.7	19	7.1	19(g)	1	5	4.9	2	8
		6.1	23.0	7.8	20	6.8	—	—	—	—	—	—
		9.1	16.0	9.8	—	—	—	—	—	—	—	—
		11.0	13.0	4.2	26	5.8	—	—	—	—	—	—
	29 Oct 85	0.0	9.5	9.5	19	5.7	12(g)	2	5	6.1	4	11
		13.1	9.5	9.5	28	5.1	—	—	—	—	—	—
	3 Feb 86	0.9	0.9	11.1	22	6.2	16(g)	2	5	6.7	—	9
		7.6	4.0	4.0	32	6.1	—	—	—	—	—	—
		13.4	4.3	3.3	35	6.1	—	—	—	—	—	—
Lower Bass (Langlade)	8 Jul 85**	0.0	24.5	7.5	—	5.9	24(g)	1	—	5.3	3	11
		3.0	21.5	7.6	—	5.6	—	—	—	—	—	—
		4.0	17.0	6.8	—	—	—	—	—	—	—	—
		5.0	12.0	2.9	—	5.4	—	—	—	—	—	—
	5 Aug 85	0.0	24.5	7.3	13	5.9	21(g)	1	15	4.6	—	9
		3.0	23.2	7.4	18	5.8	—	—	—	—	—	—
		5.5	15.0	0.8	22	5.4	—	—	—	—	—	—
	14 Oct 85	0.0	11.5	9.9	16	5.5	11(g)	1	15	4.6	2	10
		5.2	10.0	8.9	17	5.4	—	—	—	—	—	—
	22 Jan 86	0.9	3.0	11.3	17	5.3	20	1	15	3.0	—	13
		3.0	4.7	2.1	—	—	—	—	—	—	—	—
		5.5	5.0	0.7	25	5.3	—	—	—	—	—	—
Metonga (Forest)	6 Aug 85**	0.0	21.5	7.8	187	8.5	1,646	20	5	4.6	4	13
		10.7	19.5	2.9	192	7.6	—	—	—	—	—	—
		13.7	18.0	0.6	—	—	—	—	—	—	—	—
		21.7	15.7	0.0	204	7.3	—	—	—	—	—	—
	28 Aug 85	0.0	19.0	8.6	188	8.2	1,740	20	10	5.0	8	18
		12.2	18.5	7.0	193	8.0	—	—	—	—	—	—
		18.3	18.1	5.6	—	—	—	—	—	—	—	—
		21.3	17.5	2.6	—	—	—	—	—	—	—	—
		23.2	16.0	0.0	221	7.3	—	—	—	—	—	—
	14 Oct 85	0.0	13.0	9.1	175	7.8	1,640	21	5	9.1	2	18
		22.9	12.0	7.8	177	7.7	—	—	—	—	—	—
	3 Feb 86	0.9	0.8	11.8	216	7.2	1,860	21	5	6.4	—	13
		10.7	3.1	9.4	213	7.2	—	—	—	—	—	—
		21.6	4.5	3.4	221	7.2	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Monona (Dane)	17 Jun 85	0.0	19.5	9.4	—	—	—	—	—	2.5	30	71
		10.0	18.2	6.4	—	—	—	—	—	—	—	—
		16.0	17.3	0.3	—	—	—	—	—	—	—	—
	29 Jul 85	0.0	25.0	9.0	—	8.9	3,226	29	—	1.1	21	78
		9.0	23.0	3.5	—	8.5	—	—	—	—	—	—
		12.0	19.0	0.0	—	7.5	—	—	—	—	—	—
		21.5	18.0	0.0	—	7.2	—	—	—	—	—	—
	26 Nov 85	0.0	4.0	10.8	416	8.3	3,160	34	15	2.4	4	75
		21.3	4.0	10.6	416	8.3	—	—	—	—	—	—
	21 Jan 86	0.9	0.3	12.5	425	7.7	3,400	36	5	9.3	—	—
		9.1	1.9	11.5	448	7.8	—	—	—	—	—	—
		19.8	3.7	0.8	600	7.6	—	—	—	—	—	—
Noquebay (Marinette)	16 Jul 85	0.0	22.5	7.6	266	8.7	2,680	33	30	3.7	2	11
		7.6	19.2	4.4	267	8.1	—	—	—	—	—	—
		13.7	18.1	1.4	281	7.8	—	—	—	—	—	—
	13 Aug 85**	0.0	22.2	7.5	—	8.4	2,785	33	—	3.2	5	15
		6.0	22.0	7.2	—	8.4	—	—	—	—	—	—
		10.0	19.2	0.3	—	7.4	—	—	—	—	—	—
		14.0	19.0	0.0	—	7.4	—	—	—	—	—	—
	2 Oct 85	0.0	12.0	8.9	255	8.2	2,600	34	40	3.0	2	15
		13.4	12.0	9.0	270	8.0	—	—	—	—	—	—
	8 Jan 86	1.0	0.0	9.6	287	7.3	2,820	40	40	3.0	—	9
		9.1	3.0	5.9	290	7.4	—	—	—	—	—	—
		13.7	3.5	4.9	188	7.4	—	—	—	—	—	—
North Two (Oneida)	2 Jul 85	0.0	22.5	8.1	18	6.3	70	1	5	4.6	2	6
		6.1	18.7	9.0	21	6.4	—	—	—	—	—	—
		12.8	9.0	2.0	26	5.8	—	—	—	—	—	—
	5 Aug 85**	0.0	23.0	8.3	—	6.2	57(g)	1	—	6.8	1	8
		8.0	17.0	10.7	—	5.8	—	—	—	—	—	—
		10.0	9.5	0.5	—	—	—	—	—	—	—	—
		13.8	7.4	0.0	—	5.4	—	—	—	—	—	—
	29 Oct 85	0.0	10.0	10.1	17	6.3	50(g)	1	5	4.0	4	9
		14.0	10.0	9.9	25	6.3	—	—	—	—	—	—
	4 Feb 86	0.9	0.8	13.6	21	6.5	69(g)	2	5	4.6	—	9
		7.6	3.3	4.6	23	6.4	—	—	—	—	—	—
		13.7	4.3	6.8	21	6.3	—	—	—	—	—	—
Pike (Washington)	17 Jul 85**	0.0	25.7	9.2	—	8.4	3,670	35	—	1.7	10	19
		7.0	20.5	1.1	—	7.5	—	—	—	—	—	—
		8.0	19.5	0.0	—	—	—	—	—	—	—	—
		12.5	12.5	0.0	—	7.1	—	—	—	—	—	—
	15 Aug 85	0.0	24.5	8.6	545	8.7	3,500	31	15	1.8	5	17
		6.1	22.8	5.0	588	8.5	—	—	—	—	—	—
		9.1	20.0	0.3	—	—	—	—	—	—	—	—
		12.8	17.4	0.0	694	7.4	—	—	—	—	—	—
	26 Nov 85	0.0	2.0	12.6	526	8.1	3,700	44	20	2.4	5	21
		12.5	2.0	12.4	563	8.4	—	—	—	—	—	—
	31 Jan 86	0.9	1.5	9.7	635	7.7	4,380	48	15	4.6	—	20
		6.1	2.0	8.2	647	7.8	—	—	—	—	—	—
		11.6	2.5	5.5	728	7.8	—	—	—	—	—	—
Pine (Waukesha)	17 Jul 85**	0.0	25.0	8.9	—	8.7	2,800	25	—	52.0	4	16
		11.0	15.2	5.5	—	7.9	—	—	—	—	—	—
		15.0	7.7	3.0	—	—	—	—	—	—	—	—
		20.0	6.1	4.8	—	—	—	—	—	—	—	—
		22.0	5.8	1.9	—	—	—	—	—	—	—	—
		24.2	5.7	0.0	—	7.1	—	—	—	—	—	—
	15 Aug 85	0.0	25.0	8.6	320	8.9	2,600	4	10	2.0	4	19
		9.1	21.0	4.6	—	—	—	—	—	—	—	—
		12.2	13.5	0.4	—	—	—	—	—	—	—	—
		13.7	10.0	0.7	355	7.7	—	—	—	—	—	—
		26.9	6.0	0.0	359	7.4	—	—	—	—	—	—
	26 Nov 85	0.0	5.0	10.1	356	8.0	2,780	3	10	3.0	3	34
		26.9	5.0	9.9	348	8.2	—	—	—	—	—	—
	31 Jan 86	0.9	0.5	13.0	338	8.0	3,060	—	5	3.0	—	27
		15.2	2.0	10.5	366	8.0	—	—	—	—	—	—
		25.9	2.5	7.7	348	7.9	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Rock	28 Jun 85**	0.0	23.0	9.2	—	8.8	3,590	39	—	2.6	6	16
(Jefferson)		11.0	20.1	5.0	—	8.1	—	—	—	—	—	—
		14.7	19.9	2.8	—	7.7	—	—	—	—	—	—
	30 Jul 85	0.0	24.3	8.0	—	8.1	3,536	36	—	2.1	7	12
		10.0	22.5	1.6	—	—	—	—	—	—	—	—
		11.0	20.6	0.6	—	6.8	—	—	—	—	—	—
		16.0	19.1	0.0	—	7.3	—	—	—	—	—	—
	26 Nov 85	0.0	2.5	11.5	395	8.3	3,460	40	10	2.4	9	21
		15.2	2.5	11.7	392	8.5	—	—	—	—	—	—
	30 Jan 86	0.9	1.0	13.5	676	8.1	3,760	41	10	3.4	—	18
		9.1	2.0	9.5	696	8.0	—	—	—	—	—	—
		15.2	3.5	6.2	701	7.9	—	—	—	—	—	—
Round	14 Aug 85	0.0	21.0	7.8	17	6.0	70	2	20	1.7	6	21
(Chippewa)		4.9	21.0	7.7	19	6.3	—	—	—	—	—	—
	21 Aug 85**	0.0	19.8	8.6	—	—	5(g)	1	—	2.3	5	21
		5.0	18.5	7.9	—	—	—	—	—	—	—	—
	23 Oct 85	0.0	11.5	9.2	20	6.1	42(g)	1	20	2.1	6	16
		4.6	11.5	10.2	23	6.2	—	—	—	—	—	—
	13 Feb 86	0.9	0.5	13.2	11	6.9	77(g)	2	20	2.4	—	13
		4.3	4.0	3.0	31	6.5	—	—	—	—	—	—
Sand	1 Jul 85	0.0	25.5	8.0	39	6.9	200	3	80	1.8	4	23
(Oneida)		5.5	19.0	4.9	45	6.4	—	—	—	—	—	—
	6 Aug 85	0.0	23.2	—	—	6.0	229(g)	4	—	1.7	11	34
		5.0	22.5	6.8	—	5.6	—	—	—	—	—	—
	29 Oct 85	0.0	9.5	9.5	39	6.6	196(g)	4	80	1.2	5	24
		4.0	9.5	9.4	41	6.7	—	—	—	—	—	—
	4 Feb 86	0.9	0.5	4.4	54	6.2	303(g)	5	120	0.9	—	26
		3.7	4.2	3.2	52	6.1	—	—	—	—	—	—
Sand	22 Jul 85**	0.0	25.0	10.3	—	9.1	1,140	14	—	1.5	21	27
(Polk)		5.0	21.0	3.4	—	—	—	—	—	—	—	—
		6.0	18.0	1.4	—	6.4	—	—	—	—	—	—
		9.0	12.0	0.0	—	—	—	—	—	—	—	—
		12.0	7.5	0.0	—	6.2	—	—	—	—	—	—
		18.8	6.2	0.0	—	6.1	—	—	—	—	—	—
	26 Aug 85	0.0	20.5	8.0	134	8.8	1,100	15	15	1.7	10	23
		9.1	11.5	1.5	144	7.3	—	—	—	—	—	—
		18.3	8.0	0.0	149	7.1	—	—	—	—	—	—
	21 Oct 85	0.0	11.0	8.8	137	7.3	1,060	15	15	2.1	12	36
		18.3	10.0	5.5	140	7.2	—	—	—	—	—	—
	10 Feb 86	0.9	1.5	11.3	164	7.0	1,220	17	5	7.6	—	23
		9.1	3.0	5.2	160	7.0	—	—	—	—	—	—
		17.7	4.0	2.0	162	6.9	—	—	—	—	—	—
Sand	24 Jul 85**	0.0	22.0	8.0	—	7.7	676	9	—	3.5	10	20
(Sawyer)		7.0	18.0	0.4	—	6.3	—	—	—	—	—	—
		15.0	15.3	0.0	—	6.1	—	—	—	—	—	—
	26 Aug 85	0.0	21.0	9.0	77	7.7	600	9	20	1.5	15	42
		7.6	19.0	7.3	79	7.6	—	—	—	—	—	—
		12.2	18.1	4.8	—	—	—	—	—	—	—	—
		14.6	16.0	0.0	161	7.1	—	—	—	—	—	—
	21 Oct 85	0.0	10.0	8.9	68	7.1	480	8	35	2.7	4	31
		14.0	10.0	8.3	76	7.1	—	—	—	—	—	—
	12 Feb 86	0.9	0.4	11.5	76	6.6	510(g)	9	20	4.0	—	18
		7.6	3.0	9.0	85	6.7	—	—	—	—	—	—
		14.3	5.0	4.0	162	6.6	—	—	—	—	—	—
Scott	23 Jul 85**	0.0	24.3	9.0	—	6.4	141(g)	2	—	1.5	16	27
(Barron)		3.5	23.9	8.7	—	5.2	—	—	—	—	—	—
		5.0	15.4	1.3	—	—	—	—	—	—	—	—
		7.0	10.5	0.0	—	5.4	—	—	—	—	—	—
	26 Aug 85	0.0	22.0	8.6	31	7.0	154(g)	2	30	1.5	13	31
		3.7	20.0	7.1	32	6.8	—	—	—	—	—	—
		6.1	15.5	2.3	—	—	—	—	—	—	—	—
		7.3	12.5	0.0	105	6.3	—	—	—	—	—	—
	21 Oct 85	0.0	10.0	9.7	31	6.7	75(g)	2	30	1.8	15	36
		7.9	10.0	9.6	40	6.7	—	—	—	—	—	—
	10 Feb 86	0.9	0.5	9.9	42	6.7	158(g)	3	30	2.7	—	31
		4.6	3.8	2.4	41	6.6	—	—	—	—	—	—
		7.3	4.3	0.9	52	6.4	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (μmhos/cm)	pH	Alk. (μeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (μg/L)	Tot. P (μg/L)
Shawano (Shawano)	16 Jul 85	0.0	25.5	7.5	256	8.5	2,240	27	20	2.0	6	17
		6.1	24.1	6.4	258	8.5	—	—	—	—	—	—
		10.7	20.5	2.9	275	8.1	—	—	—	—	—	—
	13 Aug 85**	0.0	21.5	8.2	—	9.2	2,214	26	—	1.6	14	31
		5.8	21.5	8.2	—	9.1	—	—	—	—	—	—
	2 Oct 85	0.0	12.0	9.7	229	8.5	1,920	25	20	1.5	12	32
		12.2	12.0	9.8	231	8.7	—	—	—	—	—	—
	9 Jan 86	0.9	1.0	13.9	446	6.9	1,920	25	60	4.3	—	27
		4.6	3.5	6.3	492	6.9	—	—	—	—	—	—
		11.0	4.3	5.0	609	7.0	—	—	—	—	—	—
Shell (Washburn)	23 Jul 85**	0.0	22.2	8.8	—	8.0	120(g)	3	—	3.8	9	12
		8.5	21.9	8.8	—	7.4	—	—	—	—	—	—
		10.0	18.7	3.2	—	—	—	—	—	—	—	—
		10.9	18.2	0.0	—	—	—	—	—	—	—	—
	26 Aug 85	0.0	20.5	8.9	160	7.6	156(g)	3	5	2.1	13	20
		4.6	19.5	8.5	170	7.2	—	—	—	—	—	—
		10.7	19.5	8.1	171	7.1	—	—	—	—	—	—
	21 Oct 85	0.0	10.5	10.1	39	6.8	159(g)	3	10	4.9	2	10
		11.0	10.5	9.9	44	6.9	—	—	—	—	—	—
	10 Feb 86	0.9	0.4	13.0	51	7.6	165(g)	4	5	10.4	—	9
		4.6	1.8	11.6	51	7.5	—	—	—	—	—	—
		10.7	4.0	8.0	54	7.4	—	—	—	—	—	—
Silver, Big (Waushara)	18 Jul 85**	0.0	24.0	9.1	—	8.6	2,240	20	—	5.2	3	9
		5.0	23.8	9.1	—	8.5	—	—	—	—	—	—
		10.0	12.5	4.7	—	7.3	—	—	—	—	—	—
		13.0	8.2	0.0	—	—	—	—	—	—	—	—
		14.0	8.0	0.0	—	6.9	—	—	—	—	—	—
	8 Aug 85	0.0	23.5	8.1	244	8.9	2,140	20	10	3.4	3	10
		7.6	21.5	7.5	248	8.6	—	—	—	—	—	—
		9.1	17.3	3.3	—	—	—	—	—	—	—	—
		10.7	13.0	0.7	—	—	—	—	—	—	—	—
		13.1	10.5	0.1	258	7.3	—	—	—	—	—	—
	7 Nov 85	0.0	10.0	9.6	229	7.9	2,240	24	5	3.7	5	14
		14.0	10.0	9.4	246	8.0	—	—	—	—	—	—
	29 Jan 86	0.9	0.5	12.6	264	7.9	2,320	24	5	4.9	—	10
		7.6	2.0	11.5	269	7.7	—	—	—	—	—	—
		13.7	4.0	4.5	293	7.7	—	—	—	—	—	—
Siskiwit (Bayfield)	23 Jul 85	0.0	24.0	6.0	20	6.5	71(g)	2	120	0.8	9	30
		3.0	22.7	6.8	21	6.4	—	—	—	—	—	—
	20 Aug 85**	0.0	17.0	8.5	—	—	89(g)	2	—	1.1	8	31
		3.5	17.0	8.3	—	—	—	—	—	—	—	—
	22 Oct 85	0.0	10.5	9.9	22	6.1	62(g)	2	120	0.8	7	28
		3.4	10.5	9.6	22	6.0	—	—	—	—	—	—
	12 Feb 86	0.9	0.3	11.4	9	6.1	79(g)	3	140	0.8	—	25
		3.0	3.4	5.0	26	6.0	—	—	—	—	—	—
Sugar Camp (Oneida)	1 Jul 85	0.0	24.0	8.0	24	5.1	24	2	5	4.9	2	7
		6.1	20.2	8.5	24	5.2	—	—	—	—	—	—
		9.4	19.0	7.9	27	5.2	—	—	—	—	—	—
	7 Aug 85**	0.0	22.3	8.0	—	5.0	0(g)	2	—	6.6	4	11
		6.0	22.3	7.9	—	4.8	—	—	—	—	—	—
		10.4	21.8	5.9	—	4.7	—	—	—	—	—	—
	28 Oct 85	0.0	10.0	10.3	25	5.4	-1(g)	2	5	4.0	2	9
		9.4	10.0	10.1	30	5.3	—	—	—	—	—	—
	4 Feb 86	0.9	1.0	13.6	26	5.3	6(g)	2	0	8.2	—	8
		4.6	2.2	11.3	31	5.4	—	—	—	—	—	—
		8.8	3.9	5.4	33	5.2	—	—	—	—	—	—
Tahkodah (Bayfield)	24 Jul 85	0.0	22.5	7.7	14	6.7	37(g)	1	10	3.2	3	11
		4.9	22.5	7.7	13	6.6	—	—	—	—	—	—
	19 Aug 85**	0.0	19.0	8.5	—	—	51(g)	1	—	3.4	5	14
		4.5	19.0	8.2	—	—	—	—	—	—	—	—
	23 Oct 85	0.0	10.5	10.4	17	6.4	38(g)	1	5	4.0	3	12
		4.9	10.5	10.5	17	6.4	—	—	—	—	—	—
	12 Feb 86	0.9	0.0	13.4	20	6.4	48	2	5	5.2	—	8
		4.6	3.5	3.4	25	6.1	—	—	—	—	—	—

APPENDIX TABLE 2. *Continued.*

Lake (County)	Sampling Date	Depth (m)	Temp. (C)	DO (mg/L)	Conduct. (µmhos/cm)	pH	Alk. (µeq/L)	Ca (mg/L)	Color (Pt-Co)	Secchi (m)	Chl-*a* (µg/L)	Tot. P (µg/L)
Twenty-Six (Burnett)	23 Jul 85**	0.0	23.5	8.8	—	7.8	928	12	—	4.5	3	9
		6.0	16.8	9.6	—	7.2	—	—	—	—	—	—
		9.0	8.5	1.0	—	6.2	—	—	—	—	—	—
		10.0	7.7	0.0	—	—	—	—	—	—	—	—
		13.5	7.0	0.0	—	6.0	—	—	—	—	—	—
	27 Aug 85	0.0	19.5	8.8	93	8.4	900	13	5	2.9	4	12
		7.6	13.5	1.4	103	7.1	—	—	—	—	—	—
		9.1	10.5	0.4	—	—	—	—	—	—	—	—
		13.1	8.5	0.0	181	7.0	—	—	—	—	—	—
	22 Oct 85	0.0	10.5	8.8	284	7.3	900	14	15	2.4	4	21
		12.2	10.0	7.1	292	7.2	—	—	—	—	—	—
	11 Feb 86	0.9	0.8	11.0	109	6.8	1,000	15	10	6.4	—	11
		6.1	3.7	6.7	111	6.8	—	—	—	—	—	—
		12.2	4.6	4.2	160	6.8	—	—	—	—	—	—
Twin Bear (Bayfield)	23 Jul 85	0.0	24.5	8.0	113	8.2	1,020	15	10	5.8	1	5
		9.1	12.5	7.0	115	7.6	—	—	—	—	—	—
		12.2	10.0	0.7	—	—	—	—	—	—	—	—
		16.5	9.5	0.2	126	7.0	—	—	—	—	—	—
	20 Aug 85**	0.0	19.0	8.5	—	7.2	1,118	15	—	5.6	2	8
		9.0	12.0	6.3	—	—	—	—	—	—	—	—
		11.0	9.0	0.2	—	6.5	—	—	—	—	—	—
		17.2	8.0	—	—	6.5	—	—	—	—	—	—
	23 Oct 85	0.0	10.5	9.9	112	7.3	1,020	16	10	3.0	5	27
		17.1	9.5	8.4	114	7.4	—	—	—	—	—	—
	12 Feb 86	0.9	1.0	10.0	126	7.0	1,160	17	5	10.7	—	8
		9.1	3.8	4.8	133	7.0	—	—	—	—	—	—
		16.5	4.4	2.8	139	7.0	—	—	—	—	—	—
White Birch (Vilas)	11 Jul 85**	0.0	22.0	8.7	—	9.0	557(g)	7	—	6.0	4	14
		4.0	21.0	8.0	—	7.8	—	—	—	—	—	—
		6.0	18.3	4.5	—	6.6	—	—	—	—	—	—
	7 Aug 85	0.0	23.0	8.1	64	8.8	580	7	10	4.0	4	11
		3.0	22.8	8.0	65	8.9	—	—	—	—	—	—
		6.4	21.5	1.9	75	6.9	—	—	—	—	—	—
	15 Oct 85	0.0	9.0	9.5	58	7.4	531(g)	7	10	4.0	4	16
		6.7	9.0	9.8	60	7.5	—	—	—	—	—	—
	23 Jan 86	0.9	1.0	9.7	64	6.3	520	8	5	5.2	—	14
		3.7	4.0	2.1	67	6.3	—	—	—	—	—	—
		6.7	5.0	0.5	82	6.4	—	—	—	—	—	—
Wind (Racine)	2 Jul 85**	0.0	24.5	10.2	—	8.9	3,060	43	—	1.1	25	50
		4.5	21.2	3.5	—	—	—	—	—	—	—	—
		5.5	20.3	1.2	—	7.7	—	—	—	—	—	—
		8.0	19.5	0.0	—	7.6	—	—	—	—	—	—
		13.0	17.9	0.0	—	7.6	—	—	—	—	—	—
	30 Jul 85	0.0	24.2	5.8	—	8.1	3,936	39	—	1.7	20	40
		8.0	19.7	0.0	—	7.1	—	—	—	—	—	—
		15.0	16.5	0.0	—	6.6	—	—	—	—	—	—
	25 Nov 85	0.0	1.5	10.6	535	7.7	3,040	48	40	0.6	22	87
		12.5	2.0	11.2	572	7.8	—	—	—	—	—	—
	30 Jan 86	0.9	2.0	7.9	810	7.3	3,480	54	30	2.9	—	55
		7.6	2.3	6.1	1,088	7.4	—	—	—	—	—	—
		14.6	3.0	3.0	1,104	7.5	—	—	—	—	—	—

*(g) signifies that the alkalinity was determined by the gran titration method.
**Sediment samples were taken.
[a]Data collected by Wisconsin State Park Service.

APPENDIX TABLE 3. *Sediment data from mercury study lakes.**

Lake	Lake Depth (m)	Ig** (%)	(mg/g dry weight) Kjdl. N	P	Ca	Mg	Fe	S	Al	Mn	Na	K	(µg/g dry weight) B	Cd	Cr	Cu	Ni	Zn	Li	Co	As	Pb	Mo	Hg
Amnicon	4.6	41.5	17.3	3.8	8.7	3.7	107.3	3.2	14.9	2.45	0.4	1.8	18	19.2	23	25	37	206	8.1	8.5	34	124	<0.5	0.2
	8.5	38.0	16.4	3.9	6.9	3.7	107.5	3.3	15.5	1.43	0.5	1.7	18	19.8	25	26	19	206	8.2	8.9	25	134	<0.5	0.2
Bass	4.3	20.6	8.0	1.0	5.4	3.2	11.9	1.8	20.0	0.14	0.3	2.4	19	2.9	24	18	21	110	10.4	6.7	8	49	<0.5	0.1
	8.5	30.6	11.7	1.4	5.1	3.8	13.7	3.0	25.4	0.15	0.4	2.8	19	3.5	37	27	24	116	12.3	7.1	9	75	<0.5	0.2
	12.2	38.9	16.0	1.8	4.5	3.9	15.4	4.6	28.4	0.17	0.5	2.8	20	4.5	41	34	26	144	12.7	8.5	14	61	<0.5	0.2
Big Muskellunge	8.5	63.0	34.2	2.8	11.7	2.8	13.2	6.5	8.2	0.16	<0.3	2.5	23	3.1	24	16	8	87	4.7	12.4	12	88	0.5	0.1
	14.0	—	—	2.8	8.1	2.9	11.4	8.8	10.0	0.10	<0.3	2.8	—	—	—	26	—	113	—	—	—	—	—	<0.1
	19.8	56.0	27.2	2.8	7.1	3.3	12.9	9.3	11.0	0.10	<0.3	2.0	25	3.5	22	23	12	132	6.5	4.4	15	116	0.6	0.1
Butternut	6.1	5.6	2.3	0.9	4.1	2.3	43.4	0.4	6.4	5.01	0.3	0.7	14	6.7	5	4	42	29	4.1	3.4	30	11	<0.5	<0.1
	9.2	27.0	13.4	3.8	5.9	4.2	92.3	2.2	13.4	6.21	<0.3	2.1	24	14.7	17	18	101	80	8.4	6.8	149	59	<0.5	0.1
	12.8	29.4	14.0	4.1	6.6	4.3	85.5	2.3	11.9	3.70	<0.3	1.8	21	14.1	20	19	60	94	8.1	6.8	79	68	<0.5	0.1
Cedar	6.1	33.7	15.0	1.3	20.4	4.6	20.1	5.2	12.1	1.34	<0.3	1.4	20	3.5	50	24	39	68	8.5	11.7	176	78	—	0.1
	8.8	24.0	12.5	2.4	50.7	6.3	17.8	5.1	7.4	2.14	<0.3	1.4	20	2.6	19	20	25	42	4.4	2.9	15	26	<0.5	<0.1
Clark	3.7	12.7	5.3	0.3	278.9	9.9	2.8	6.3	2.8	0.11	<0.3	0.7	13	0.9	2	7	2	32	2.0	0.8	<6	23	<0.5	<0.1
	7.3	11.1	5.2	0.2	317.0	10.8	2.6	6.5	2.8	0.13	<0.3	0.6	13	0.9	3	7	2	38	1.7	0.9	<6	23	<0.5	<0.1
Clear	3.0	47.0	16.4	1.4	3.4	2.2	15.1	3.4	16.6	0.09	<0.3	2.4	18	3.1	22	14	11	80	7.6	2.3	15	79	<0.5	0.2
	6.8	51.3	20.1	1.6	3.3	2.6	11.3	4.0	18.8	0.10	<0.3	2.8	19	3.0	25	20	14	75	9.1	2.3	12	80	<0.5	0.2
Crystal	10.0	31.8	16.6	1.6	84.2	27.9	12.1	11.6	11.4	0.28	0.5	2.3	25	3.0	18	142	8	169	8.9	4.0	23	201	<0.5	0.1
	18.6	29.3	14.5	1.7	70.9	28.1	10.4	8.8	9.6	0.20	0.5	1.9	22	2.4	15	106	7	146	7.6	0.1	24	172	0.5	0.1
Delavan	5.0	6.1	2.4	0.4	274.7	11.9	3.2	5.7	2.2	0.28	0.4	0.5	12	0.6	2	12	1	17	0.5	0.9	<6	3	<0.5	<0.1
	11.0	16.2	7.2	1.2	175.5	11.0	12.7	8.2	16.8	0.69	<0.3	2.3	19	2.3	16	44	8	64	10.0	2.8	9	18	<0.5	<0.1
	16.0	15.9	6.8	1.0	208.1	12.0	11.1	9.4	11.6	0.54	<0.3	1.7	18	1.6	13	34	7	53	6.0	2.4	8	11	<0.5	<0.1
Devils	9.2	20.4	9.8	2.3	5.6	4.5	29.7	3.4	27.3	1.27	<0.3	2.5	21	6.3	35	36	37	182	15.4	7.8	13	75	<0.5	0.2
	13.4	23.8	10.9	5.7	5.9	4.3	39.2	3.7	26.9	0.56	<0.3	2.4	21	7.8	34	40	30	183	15.6	6.8	13	70	<0.5	0.2
Dowling	4.0	38.2	15.6	2.8	6.6	3.4	45.8	3.7	16.2	0.83	0.6	1.3	17	9.0	23	19	12	199	8.4	8.2	11	63	<0.5	0.3
Emily	4.0	3.5	1.3	0.4	6.9	5.6	15.1	1.4	6.8	4.68	<0.3	1.2	20	2.1	9	9	75	30	5.5	4.6	33	12	<0.5	0.2
	9.0	49.4	23.8	1.9	10.2	5.0	26.7	27.5	12.4	1.78	<0.3	2.3	30	5.7	22	39	29	171	8.3	6.8	62	79	1.1	<0.1
	13.0	47.5	21.0	1.5	8.2	4.2	23.8	25.2	9.1	2.34	<0.3	1.4	27	4.6	19	34	35	140	5.7	5.4	73	77	2.8	<0.1
Franklin	4.6	34.2	11.0	1.7	2.7	3.5	19.1	4.1	25.9	0.15	<0.3	2.5	17	5.2	37	26	16	119	13.4	5.1	8	84	1.0	0.1
	7.6	39.8	14.9	1.5	2.6	3.3	13.9	4.7	23.7	0.11	<0.3	2.5	18	5.7	37	31	18	144	13.0	5.4	<6	116	0.7	0.1
Grindstone	11.3	1.7	0.6	0.2	1.3	0.9	14.0	0.2	2.3	0.22	0.3	0.4	12	1.5	3	2	1	12	1.2	1.7	<6	7	<0.5	<0.1
	17.1	35.1	18.1	5.3	4.6	2.3	32.5	6.5	6.3	0.98	0.4	1.7	25	5.7	19	16	9	72	4.0	4.0	14	67	<0.5	0.1
Jag	4.0	52.9	24.4	1.6	4.2	3.4	12.6	4.7	16.7	0.16	<0.3	2.1	18	4.5	29	31	18	138	9.4	6.7	13	92	0.4	0.2
Joyce	12.5	55.5	26.1	2.6	3.6	2.5	10.2	8.4	16.6	0.08	<0.3	2.2	19	4.5	24	31	13	220	7.8	3.2	10	86	0.5	0.2
Little Arbor Vitae	5.8	50.2	28.1	5.9	9.4	2.4	93.5	5.2	6.8	2.15	<0.3	1.1	27	14.8	13	16	25	93	3.7	4.3	24	73	<0.5	0.1
	9.2	47.4	26.3	9.6	6.4	2.2	107.0	5.3	5.6	4.14	<0.3	1.0	25	16.8	11	15	61	84	3.0	3.8	34	60	<0.5	0.1
Little Green	3.9	26.7	12.9	1.5	34.1	8.0	22.3	4.1	20.8	2.28	<0.3	2.8	27	4.0	26	16	23	83	11.1	6.5	21	46	<0.5	0.1
	8.2	32.6	15.1	2.8	17.0	6.4	26.9	8.0	21.0	1.45	0.4	2.9	26	4.0	26	16	37	82	10.8	6.0	20	17	<0.5	<0.1
Long	6.0	56.6	21.4	1.4	3.0	2.1	8.9	5.4	15.1	0.21	<0.3	2.0	17	3.4	20	21	12	151	8.2	4.3	13	138	0.8	0.2
	10.5	62.0	24.7	1.7	3.1	1.9	7.1	5.7	13.5	0.07	<0.3	2.1	17	2.9	19	21	11	92	7.6	2.5	10	81	<0.5	<0.1
Lost	4.0	23.3	8.6	1.1	2.9	2.0	11.2	1.9	11.0	0.14	<0.3	1.9	17	1.8	14	9	8	50	5.8	2.2	13	65	<0.5	<0.1
	9.0	55.2	24.7	2.2	5.6	2.6	9.2	6.2	15.2	0.11	<0.3	2.8	21	4.4	22	25	14	139	8.1	4.1	10	103	<0.5	0.2
	14.0	59.9	27.1	2.5	5.0	2.6	8.6	8.6	14.9	0.09	<0.3	2.6	21	6.0	21	28	14	254	7.6	3.4	13	107	0.5	<0.1
Lower Bass	4.0	61.8	24.0	1.8	3.9	2.3	9.4	6.0	15.8	0.12	<0.3	2.5	19	3.4	22	21	13	130	7.5	3.2	11	65	<0.5	0.1
	6.0	64.2	26.2	1.9	4.7	2.4	9.9	6.7	15.7	0.15	<0.3	2.5	19	4.0	23	21	13	137	7.7	3.4	14	52	<0.5	0.1
Metonga	9.0	0.8	0.4	0.2	1.5	0.9	6.0	0.1	2.3	0.30	<0.3	0.4	13	0.3	4	1	1	8	1.7	1.1	8	<3	<0.5	<0.1
	12.0	41.6	21.0	2.7	7.7	4.2	35.2	5.3	10.5	1.20	<0.3	1.6	45	7.1	29	112	17	135	7.7	4.9	17	110	<0.5	0.2
	21.7	36.1	17.4	5.9	5.6	3.3	45.8	6.1	8.3	2.16	<0.3	1.2	36	7.7	21	91	29	110	5.8	3.7	22	86	<0.5	0.1

APPENDIX TABLE 3. *Continued.*

Lake	Lake Depth (m)	Ig** (%)	(mg/g dry weight) Kjdl. N	P	Ca	Mg	Fe	S	Al	Mn	Na	K	(µg/g dry weight) B	Cd	Cr	Cu	Ni	Zn	Li	Co	As	Pb	Mo	Hg
Monona	4.0	4.2	2.0	0.4	144.0	33.7	5.8	5.2	3.8	0.44	<0.3	1.1	15	0.5	31	29	4	102	<0.7	2.8	12	39	<0.5	<0.1
	13.0	15.8	7.5	1.3	150.3	17.4	16.8	11.5	16.2	0.80	<0.3	2.7	24	4.1	159	184	14	416	8.9	5.2	23	86	<0.5	0.8
	19.0	21.2	9.5	1.6	160.2	15.5	13.2	11.3	11.6	1.06	<0.3	2.1	24	2.9	99	106	13	271	6.3	3.6	15	72	<0.5	0.1
Noquebay	9.2	2.3	1.5	0.3	17.1	8.8	16.2	0.5	2.2	0.64	0.3	0.5	14	2.0	3	3	87	18	1.2	1.9	62	7	<0.5	<0.1
	13.8	47.1	19.7	2.9	23.1	7.4	79.3	6.4	8.9	5.21	0.4	1.2	25	13.9	34	40	87	121	6.4	6.6	7	59	<0.5	0.2
North Two	5.5	2.0	0.8	0.2	1.1	0.9	4.9	0.2	4.4	0.07	<0.3	0.7	13	0.5	3	1	3	13	3.2	1.3	<6	9	<0.5	<0.1
	14.6	43.6	17.6	2.3	2.6	3.0	16.8	5.8	20.7	0.12	<0.3	2.3	19	5.3	31	24	15	121	11.6	4.7	<6	103	<0.5	0.1
Pike	4.6	7.6	3.0	0.1	340.6	6.4	2.1	6.2	1.3	0.17	0.4	0.3	12	0.7	2	3	1	8	<0.7	<0.5	<7	3	<0.5	<0.1
	8.2	15.8	7.1	0.6	273.9	9.8	5.6	8.5	5.4	0.35	0.4	0.9	17	1.2	8	9	3	36	3.5	1.4	7	19	<0.5	<0.1
	13.0	17.3	7.1	0.8	244.9	9.2	5.5	8.0	5.7	0.33	0.4	0.8	17	1.1	8	10	4	35	3.6	1.3	7	22	<0.5	<0.1
Pine	6.1	21.4	9.3	0.7	202.1	16.8	7.7	7.3	6.9	0.74	<0.3	1.3	21	1.7	8	172	3	76	4.4	1.9	168	38	<0.5	0.1
	16.1	34.7	16.5	1.4	69.5	13.9	11.9	10.4	12.7	0.28	0.3	2.2	29	3.1	19	229	10	139	8.8	4.0	359	93	<0.5	0.2
	25.0	39.0	17.5	1.6	72.8	14.7	12.2	11.0	10.3	0.39	0.4	2.0	40	2.8	15	140	10	135	7.0	3.5	505	114	1.9	0.2
Rock	5.0	17.0	8.2	0.6	193.2	13.1	9.8	9.1	8.9	0.70	<0.3	1.7	18	2.0	7	9	2	81	4.9	1.9	<6	24	<0.5	<0.1
	11.0	22.1	11.2	0.8	193.9	10.4	9.3	11.0	8.1	0.72	<0.3	1.6	20	1.9	8	9	3	68	4.3	1.8	<6	21	<0.5	<0.1
	15.0	20.8	9.8	0.8	180.9	9.5	7.9	9.6	7.1	0.61	<0.3	1.4	17	1.5	7	8	3	62	4.0	1.6	<6	19	<0.5	<0.1
Round	5.5	47.9	21.7	1.6	5.0	2.7	14.0	4.7	17.9	0.30	<0.3	2.1	17	4.3	26	21	16	116	10.8	6.4	<6	65	<0.5	0.2
Sand (Oneida)	5.9	42.6	13.4	2.1	7.3	2.8	107.4	2.4	16.7	2.85	0.3	1.2	17	20.1	30	16	42	150	7.0	10.1	26	75	<0.5	0.3
Sand (Polk)	6.4	3.2	1.4	0.3	2.1	1.6	8.0	0.5	5.9	0.14	<0.3	0.8	18	0.9	8	7	6	23	4.2	3.1	8	7	<0.5	<0.1
	12.2	23.8	12.3	1.9	5.0	4.6	23.5	5.2	21.7	0.53	0.3	2.5	19	4.2	35	30	21	96	13.6	7.5	14	38	<0.5	0.1
	21.3	24.2	12.3	3.3	5.0	4.7	30.8	7.7	21.4	0.75	<0.3	2.4	21	5.3	35	35	21	92	13.5	7.8	16	38	<0.5	0.1
Sand (Sawyer)	6.1	24.3	11.2	2.5	5.4	2.1	67.7	2.9	9.0	2.18	0.3	1.1	18	11.5	9	11	21	84	4.5	4.4	16	51	<0.5	0.2
	10.7	40.1	18.8	5.6	6.5	2.4	89.3	4.4	9.4	2.87	<0.3	1.1	22	17.7	19	19	43	117	5.3	5.8	32	80	<0.5	0.2
	15.3	39.2	16.1	9.2	4.8	1.4	107.7	5.6	4.2	5.31	<0.3	0.6	19	26.9	8	13	72	76	2.1	5.1	62	41	<0.5	0.2
Scott	4.3	31.2	15.9	1.7	3.8	3.7	13.6	3.2	24.5	0.17	<0.3	2.6	18	3.8	41	30	26	123	15.1	6.4	<6	55	<0.5	0.1
	7.9	34.8	18.4	2.3	3.6	3.9	16.0	4.1	25.2	0.21	<0.3	2.5	18	4.2	39	33	26	136	14.1	6.3	<6	64	<0.5	0.2
Shawano	6.1	46.9	23.8	1.5	20.9	8.0	34.2	7.5	10.1	2.59	0.5	1.9	29	6.4	17	24	41	105	6.7	5.7	32	79	<0.5	0.2
Shell	7.6	5.0	2.0	0.7	2.1	1.7	16.7	0.4	8.1	0.39	<0.3	1.1	14	2.4	7	6	7	43	4.4	3.4	<6	18	<0.5	<0.1
	11.6	27.5	12.2	2.0	3.7	4.7	29.0	2.0	23.1	0.44	<0.3	2.4	20	6.9	39	31	25	115	14.9	8.7	7	74	<0.5	0.1
Silver, Big	10.0	50.9	25.8	1.8	18.1	7.6	11.2	6.8	11.3	0.23	0.4	2.3	35	4.2	16	20	9	210	7.0	3.6	265	215	0.5	0.2
	15.8	47.5	23.4	1.6	12.5	7.0	20.3	15.2	8.4	0.21	0.5	1.5	32	4.6	15	21	8	202	5.1	3.4	1153	200	0.4	0.2
Siskiwit	3.7	35.0	11.0	1.0	5.1	6.1	23.9	2.3	23.7	0.32	0.4	3.3	20	5.2	33	24	23	101	15.3	9.3	9	67	<0.5	0.2
Sugar Camp SE	5.0	33.9	6.2	1.6	1.8	3.4	15.2	1.7	28.5	0.10	<0.3	3.4	21	3.2	30	16	13	112	15.7	4.0	10	66	<0.5	0.1
NW	9.1	1.3	0.8	0.2	0.8	0.8	4.3	0.2	3.8	0.05	<0.3	0.6	14	0.2	3	1	2	16	2.2	1.6	<6	12	<0.5	<0.1
NW	11.2	28.0	10.9	2.2	2.1	3.7	15.9	4.3	25.8	0.12	<0.3	2.7	21	5.2	34	27	18	167	14.6	6.0	10	106	<0.5	0.1
Tahkodah	4.9	36.4	16.8	1.2	3.4	3.3	11.8	3.7	17.4	0.16	0.4	2.3	17	3.8	28	24	16	152	10.3	6.3	9	95	<0.5	0.1
Twenty-Six	9.1	39.0	19.8	1.5	5.4	2.3	20.6	10.4	7.4	0.31	0.3	1.5	22	5.2	35	14	7	103	5.8	4.8	24	59	<0.5	0.1
	14.4	41.5	21.4	6.3	5.1	1.4	96.6	12.0	4.0	1.02	0.4	0.8	18	14.8	19	12	4	68	3.2	3.4	62	47	<0.5	0.2
Twin Bear	5.5	49.1	22.7	2.1	12.5	2.6	22.3	6.5	8.4	0.27	0.4	1.5	20	4.5	33	22	9	96	6.4	4.9	22	79	<0.5	0.1
	10.8	48.7	23.7	2.7	10.2	3.1	21.8	5.2	11.2	0.58	0.5	1.8	17	4.3	38	25	10	118	7.7	5.6	27	69	<0.5	0.1
	17.4	43.7	20.0	4.0	7.0	2.7	26.3	7.8	8.7	0.46	0.4	1.2	18	4.9	32	24	9	106	6.3	4.8	27	96	<0.5	0.1
White Birch	7.0	68.4	38.4	3.8	10.5	2.6	10.5	7.0	5.0	0.42	0.4	3.3	19	2.1	10	11	3	70	3.2	2.2	10	52	0.7	0.1
Wind	8.0	20.5	9.2	1.0	100.6	23.6	17.6	11.5	17.4	0.94	0.5	5.1	31	3.0	21	18	14	80	18.1	5.7	14	28	2.6	<0.1
	14.0	24.8	11.5	1.3	97.6	19.9	16.0	9.6	17.6	1.05	0.6	5.2	32	2.8	21	18	16	71	17.5	5.7	13	24	2.2	<0.1

*Samples collected from top 0-2 cm of sediment.
**Ig signifies ignition loss = volatile solids.

APPENDIX TABLE 4. *Walleyes collected from dataset lakes.*

Lake	County	Walleye Length (inches)	Walleye Weight (kg)	Walleye Hg (µg/g)
Amacoy	Rusk	13.7	0.49	0.20
Arrowhead	Vilas	23.5	2.27	0.50
Arrowhead	Vilas	14.2	0.40	0.23
Arrowhead	Vilas	20.9	1.45	0.39
Arrowhead	Vilas	22.3	1.69	0.42
Ashegon	Sawyer	16.1	0.75	0.36
Balsam	Polk	15.9	0.65	0.12
Balsam	Polk	20.4	1.25	0.13
Bear	Ashland	20.4	1.35	0.73
Bear	Ashland	18.5	1.22	0.58
Bear	Ashland	19.1	1.15	0.88
Bear	Ashland	19.2	1.25	0.84
Bear	Ashland	19.3	1.48	0.74
Bear	Ashland	10.5	0.14	0.35
Bear	Ashland	13.0	0.29	0.37
Bear	Ashland	13.2	0.34	0.43
Bear	Ashland	13.6	0.46	0.36
Bear	Ashland	14.0	0.42	0.46
Bear	Ashland	20.3	1.73	0.73
Bear	Barron	17.4	0.80	0.28
Bear	Barron	14.0	0.45	0.25
Bear	Barron	16.5	0.70	0.24
Bear	Barron	16.5	0.75	0.31
Bear	Barron	21.0	0.85	0.79
Bear	Barron	20.0	1.14	0.37
Bear	Barron	21.0	1.36	0.51
Bear	Barron	21.6	1.48	0.74
Beauregard	Douglas	14.1	0.45	0.40
Beauregard	Douglas	14.4	0.45	0.27
Beauregard	Douglas	15.2	0.50	0.34
Big Arbor Vitae	Vilas	22.6	—	0.28
Big Arbor Vitae	Vilas	12.6	0.30	0.10
Big Carr	Oneida	16.5	—	0.42
Big Carr	Oneida	15.0	0.52	0.59
Big Carr	Oneida	20.0	1.25	0.76
Big Carr	Oneida	21.9	1.48	0.79
Big Carr	Oneida	22.2	1.79	0.71
Big Green	Green Lake	20.5	—	0.24
Big Green	Green Lake	19.0	1.12	0.36
Bird	Oneida	20.0	—	0.56
Bird	Oneida	17.3	0.75	0.55
Bird	Oneida	18.7	0.90	0.40
Bird	Oneida	21.7	1.42	0.80
Bird	Oneida	22.0	1.65	0.71
Bird	Oneida	15.6	0.46	0.54
Bird	Oneida	17.8	0.67	0.57
Bird	Oneida	19.4	1.00	0.46
Bird	Oneida	21.0	1.32	0.44
Brandy	Vilas	23.0	1.80	0.49
Buffalo	Oneida	9.7	—	0.25
Bullhead	Manitowoc	16.4	0.74	0.22
Bullhead	Manitowoc	21.3	1.75	0.57
Bullhead	Manitowoc	26.1	3.20	0.55
Carrol	Oneida	15.4	0.61	0.15
Carrol	Oneida	20.2	1.21	0.39
Carrol	Oneida	20.0	1.50	0.32
Clara	Lincoln	19.4	—	0.71
Clear	Oneida	19.8	1.15	0.39
Clear	Oneida	21.3	1.31	0.47
Cranberry	Price	19.0	1.40	0.36
Currie	Oneida	20.8	—	1.10
Currie	Oneida	20.3	—	1.00
Currie	Oneida	20.1	—	1.10
Currie	Oneida	18.9	—	1.20
Currie	Oneida	11.4	0.26	0.25
Currie	Oneida	14.6	0.52	1.00
Currie	Oneida	18.1	1.05	0.76
Currie	Oneida	18.1	1.05	0.84
Currie	Oneida	15.4	0.58	0.36
Currie	Oneida	16.0	0.67	0.30
Currie	Oneida	16.3	0.61	0.62
Currie	Oneida	16.6	0.61	0.34
Elk	Price	17.8	0.90	0.66
Elk	Price	19.7	0.85	0.40
Elk	Price	12.2	0.25	0.38
Elk	Price	13.0	0.35	0.42
Elk	Price	14.4	0.45	0.23
Elk	Price	14.9	0.45	0.48
Elk	Price	15.0	0.55	0.27
Elk	Price	10.8	0.24	0.31
Escanaba	Vilas	15.2	0.48	0.15
Escanaba	Vilas	12.9	0.25	0.17
Franklin	Forest	17.4	0.72	0.25
Franklin	Forest	19.2	1.23	0.37
Geneva	Walworth	12.4	0.33	0.17
Geneva	Walworth	18.4	1.12	0.44
Geneva	Walworth	22.3	—	0.46
Geneva	Walworth	16.6	0.84	0.53
Geneva	Walworth	18.7	1.78	0.44
Geneva	Walworth	21.2	2.15	0.46
Hodstradt	Oneida	12.8	—	0.17
Hodstradt	Oneida	19.4	—	1.10
Hodstradt	Oneida	20.5	—	1.20
Hodstradt	Oneida	20.6	—	0.81
Hodstradt	Oneida	22.6	—	1.20
Hodstradt	Oneida	22.9	—	1.50
Kangaroo	Door	12.1	0.25	0.06
Kangaroo	Door	10.8	0.19	0.07
Keyes	Florence	15.5	0.60	0.28
Lac La Belle	Waukesha	16.0	0.60	0.31
Lac La Belle	Waukesha	15.5	0.56	0.17
Long	Chippewa	15.0	0.45	0.13
Long	Price	18.1	0.90	0.38
Long	Price	19.6	1.00	0.90
Long	Price	11.2	0.20	0.20
Long	Price	12.3	0.25	0.23
Long	Price	13.5	0.35	0.24
Long	Price	18.7	1.09	0.35
Long	Price	22.9	1.94	0.55
Long	Price	15.0	0.50	0.28
Long	Price	20.6	1.40	0.31
Long	Price	21.2	1.50	0.59
Long	Washburn	26.5	2.80	0.46
Lower Clam	Sawyer	10.6	0.20	0.42
Lower Clam	Sawyer	12.0	0.30	0.33
Lower Clam	Sawyer	16.8	0.68	0.29
Lower Clam	Sawyer	17.1	0.75	0.47
Lower Kaubashine	Oneida	20.6	1.36	0.60
Lt. St. Germain	Vilas	24.5	2.35	0.25
Lucerne	Forest	24.3	2.15	0.78
Lyman	Douglas	12.2	0.15	0.48
Lyman	Douglas	13.6	0.30	0.95
Lyman	Douglas	13.9	0.30	0.85
Lyman	Douglas	16.1	0.45	0.99
Lyman	Douglas	24.2	2.25	1.70
Lyman	Douglas	16.7	0.74	0.79
Lyman	Douglas	19.8	1.36	0.99
Lyman	Douglas	20.8	1.48	1.10
Lyman	Douglas	20.9	1.59	1.20
Lyman	Douglas	25.4	2.90	2.10
Mayflower	Marathon	19.1	1.20	0.51
Mayflower	Marathon	19.7	1.19	0.63
Mayflower	Marathon	22.2	1.62	0.54
Mayflower	Marathon	19.1	0.99	0.31
McGrath	Oneida	14.6	0.55	0.40
McGrath	Oneida	14.6	0.55	0.38
Mendota	Dane	20.3	1.20	0.04
Mendota	Dane	20.2	1.45	0.11
Mendota	Dane	20.8	1.65	0.24
Mendota	Dane	23.8	2.16	0.27
Menominee	Dunn	17.4	0.68	0.13
Menominee	Dunn	17.2	0.74	0.18
Mid	Oneida	22.0	1.70	0.32
Mid Eau Claire	Bayfield	17.4	0.70	0.40
Mid Eau Claire	Bayfield	25.1	2.40	0.20
Moose	Sawyer	13.4	0.31	0.46
Musser	Price	24.9	2.40	1.70
Musser	Price	22.8	1.85	0.77

APPENDIX TABLE 4. *Continued.*

Lake	County	Walleye Length (inches)	Walleye Weight (kg)	Walleye Hg (μg/g)
Musser	Price	24.7	2.60	0.81
Musser	Price	25.2	2.45	1.30
Musser	Price	12.6	0.30	0.19
Musser	Price	13.1	0.35	0.19
Musser	Price	14.3	0.50	0.24
Musser	Price	15.2	0.60	0.49
Nagawicka	Waukesha	13.3	0.35	0.12
Namekagon	Bayfield	15.7	0.50	0.34
Namekagon	Bayfield	19.3	0.87	0.87
Namekagon	Bayfield	21.1	1.48	0.50
Namekagon	Bayfield	18.4	0.89	0.70
Nebagamon	Douglas	16.0	0.60	0.40
Nelson	Sawyer	18.0	0.55	0.20
North Twin	Vilas	16.0	0.57	0.26
North Twin	Vilas	17.3	0.78	0.28
North Twin	Vilas	18.9	1.01	0.82
North Twin	Vilas	19.4	1.04	0.36
North Twin	Vilas	22.5	1.94	0.43
North Twin	Vilas	18.0	0.89	0.26
North Twin	Vilas	18.9	0.91	0.28
North Twin	Vilas	19.5	1.14	0.57
Oswego	Vilas	25.0	2.24	1.90
Otter	Langlade	17.5	0.82	0.23
Otter	Langlade	20.6	1.50	0.29
Owl	Iron	19.0	1.35	1.50
Owl	Iron	22.0	1.85	1.50
Owl	Iron	20.8	1.48	1.80
Owl	Iron	10.6	0.14	0.47
Owl	Iron	10.8	0.20	0.50
Owl	Iron	11.7	0.26	0.66
Owl	Iron	17.8	1.05	1.20
Pewaukee	Waukesha	13.3	0.35	0.22
Pine	Forest	13.4	0.35	0.17
Pine	Forest	21.7	1.76	0.90
Pine	Lincoln	20.4	1.40	0.78
Potato	Rusk	17.1	0.85	0.20
Potato	Rusk	16.2	0.80	0.15
Potato	Rusk	17.5	—	0.18
Rib	Taylor	12.9	0.30	0.43
Rib	Taylor	14.8	0.55	0.26
Rib	Taylor	16.0	0.75	0.17
Riley	Chippewa	25.0	2.25	0.75
Riley	Chippewa	26.0	2.89	0.74
Round	Burnett	13.4	0.40	0.28
Round	Sawyer	16.0	0.52	0.19
Round	Sawyer	16.5	0.60	0.18
Sand	Florence	16.5	0.70	0.85
Sand	Florence	19.1	1.20	1.00
Sand	Florence	20.1	1.40	1.00
Sand	Florence	18.0	0.91	1.20
Sand	Florence	18.3	0.91	0.83
Sand	Florence	23.6	2.16	1.20
Sand	Florence	24.4	2.16	1.10
Sand	Florence	24.8	2.56	0.85
Sand	Florence	25.8	2.16	1.30
Seven Island	Lincoln	18.0	1.35	0.47
Seventeen	Oneida	16.0	0.64	0.37
Seventeen	Oneida	21.2	1.67	1.20
Silver	Lincoln	16.0	1.20	0.82
Silver	Lincoln	13.2	0.30	0.20
Silver	Lincoln	13.8	0.35	0.19
Silver	Lincoln	14.4	0.45	0.31
Silver	Lincoln	14.9	0.44	0.37
Silver	Lincoln	15.6	0.51	0.28
Silver	Lincoln	15.7	0.54	0.34
Silver	Lincoln	17.4	0.71	0.46
Sissabagama	Sawyer	13.8	0.38	0.16
Sissabagama	Sawyer	14.0	0.40	0.18
Sissabagama	Sawyer	14.1	0.42	0.18
South Twin	Vilas	18.0	0.89	0.26
South Twin	Vilas	18.9	0.91	0.28
South Twin	Vilas	19.5	1.14	0.57
Solberg	Price	16.1	0.50	0.90
Solberg	Price	12.1	0.25	0.36
Solberg	Price	13.6	0.35	0.42
Solberg	Price	14.7	0.45	0.67
Solberg	Price	15.8	0.60	0.72
Solberg	Price	16.5	0.60	1.97
Solberg	Price	17.0	0.61	0.80
Solberg	Price	18.0	0.91	0.95
Solberg	Price	18.6	0.88	0.68
Solberg	Price	23.8	2.94	1.10
Solberg	Price	26.6	2.89	1.40
Spectacle	Vilas	15.9	—	0.44
Squaw	St. Croix	20.2	1.25	0.36
Sunset	Vilas	12.1	0.25	0.26
Tainter	Dunn	20.2	1.22	0.74
Tainter	Dunn	20.3	1.25	1.00
Tomahawk	Oneida	20.0	1.30	0.34
Tomahawk	Oneida	19.1	1.20	0.50
Trout	Vilas	21.8	1.60	1.10
Trout	Vilas	25.2	2.67	1.10
Trout	Vilas	29.1	4.55	1.10
Trout	Vilas	16.5	0.66	0.27
Trout	Vilas	30.1	4.40	1.10
Trout	Vilas	12.3	0.83	0.21
Trout	Vilas	14.0	0.39	0.14
Trout	Vilas	14.2	0.44	0.16
Trout	Vilas	14.7	0.49	0.12
Trout	Vilas	19.8	1.95	0.28
Upper Kaubashine	Oneida	19.4	0.91	0.63
Upper Kaubashine	Oneida	18.5	0.81	0.73
Upper Kaubashine	Oneida	17.4	0.68	0.19
Upper Kaubashine	Oneida	18.0	0.91	0.14
Upper Kaubashine	Oneida	18.3	0.93	0.52
Vieux Desert	Vilas	17.3	0.62	0.17
Vieux Desert	Vilas	18.4	0.82	0.19
Vieux Desert	Vilas	18.8	1.08	0.15
Waubesa	Dane	22.5	1.65	0.34
Waubesa	Dane	26.5	3.10	0.14
Waubesa	Dane	19.2	1.00	0.60
Wheeler	Oconto	13.3	0.40	0.14
Wheeler	Oconto	17.8	0.94	0.32
Wheeler	Oconto	21.4	1.85	0.34
White Potato	Oconto	17.8	0.75	0.35
White Potato	Oconto	19.7	1.20	0.32
White Potato	Oconto	19.3	0.22	0.22
Windigo	Sawyer	14.7	0.45	0.62
Windigo	Sawyer	15.2	0.55	0.63
Windigo	Sawyer	15.2	0.55	0.61
Windigo	Sawyer	15.3	0.55	0.69
Windigo	Sawyer	16.7	0.60	0.91
Windigo	Sawyer	17.3	0.75	1.10
Windigo	Sawyer	20.1	1.22	1.40
Windigo	Sawyer	20.2	1.22	0.72
Windigo	Sawyer	21.2	1.45	0.58
Windigo	Sawyer	10.4	0.17	0.42
Windigo	Sawyer	12.0	0.26	0.51
Windigo	Sawyer	11.4	0.17	0.33
Windigo	Sawyer	15.5	0.45	0.92
Windigo	Sawyer	19.2	1.05	1.00
Winnebago	Winnebago	16.1	0.95	0.09
Yellow	Burnett	16.8	0.70	0.46
Yellow	Burnett	17.5	0.79	0.31
Yellow	Burnett	20.5	1.08	0.99
Yellow	Burnett	14.7	0.46	0.27
Yellow	Burnett	15.5	0.59	0.23
Yellow	Burnett	16.7	0.76	0.34
Yellow	Burnett	17.4	0.85	0.37
Yellow	Burnett	18.3	1.06	0.29
Yellow	Burnett	19.8	1.22	0.50
Yellow	Burnett	21.4	1.55	0.52
Yellow	Burnett	23.4	2.45	0.50

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ACKNOWLEDGMENTS

Numerous people assisted at various stages in this project. Bob Masnado provided information needed for initially selecting the study lakes. Cindy Jerman played an invaluable role as coordinator of the DNR fish grinding work and data reporting for the walleyes collected on our study lakes. Al Clary and Sherry Combs gave special attention to our sediment chemistry analyses at the State Laboratory of Hygiene and the UW Soil and Plant Analysis Lab, respectively. Ann Schachte and Carol Tiegs assisted in retrieving data needed from DNR computer files. Ellie Montgomery helped analyze the lake chemistry data. Nevenah Smith entered the new research data into the computer and Jean Adams assisted in the statistical analyses and report preparation. Doug Knauer, Lee Liebenstein, and Tom Sheffy gave advice on overall project direction and provided useful comments in early reviews of the manuscript. Jerry Wegner and Greg Quinn were responsible for conducting the fall, winter, and one of the two summer lake samplings and for collecting walleyes on some of the study lakes. Their work was greatly appreciated. Bob Last and Jeff Reed also assisted on one of the summer lake sampling trips. Special thanks are also extended to Steve Greb for many helpful suggestions about the data analyses, to Dr. Tom Frost for allowing the use of the UW's Trout Lake Station in northern Wisconsin, and to George Hanson in the DNR Northwest District for kindly fixing our cracked boat trailer frame on such short notice. Funding for this project was through the DNR Bureau of Research and Bureau of Water Resources Management.

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